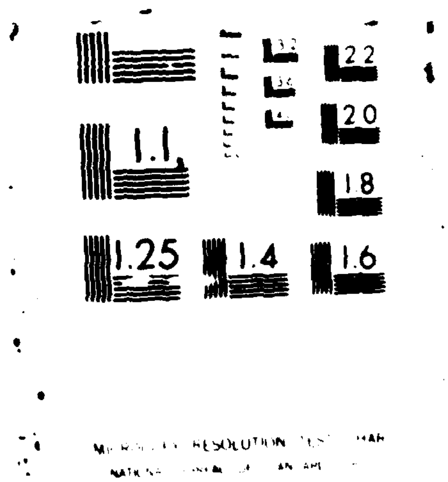
AD-A178 604 INITIAL FEASIBILITY STUDY AND BUDGET FOR A HAZARDOUS WASTE INCINERATOR AT..(U) NAVAL CIVIL ENGINEERING LAB PORT HUENEME CA W POWERS ET AL. JAN 87 NCEL-TN-1763 1/1

UNCLASSIFIED F/G 13/2 NL

END
DATE
FILMED
5-87


1.1
1.25
1.4
1.6
1.8
2.0
2.2
RESOLUTION

12

TN-1763
January 1987
By William Powers, CHMM
and Richard Lee, PhD
Sponsored By Pearl Harbor
Naval Shipyard, Hawaii

NCEL
Technical Note

AD-A178 604

INITIAL FEASIBILITY STUDY AND BUDGET FOR A HAZARDOUS WASTE INCINERATOR AT PEARL HARBOR NAVAL SHIPYARD

ABSTRACT Spurred by increasing regulatory restrictions, rising costs for transport and disposal, and the lack of suitable hazardous waste disposal sites in Hawaii, Pearl Harbor Naval Shipyard (PHNSY) is considering incineration as a potentially cost-effective and desirable means of disposal. The Naval Civil Engineering Laboratory (NCEL) at Port Hueneme, California, was accordingly tasked with preparation of this initial feasibility study and budget estimate. It is estimated that PHNSY will require a rotary kiln incinerator capable of handling 4,000 to 8,000 lb/hr of hazardous waste. Capital costs for the physical plant are estimated to range from $2,992,000 to $3,781,000. Total operation and maintenance (O&M) costs are estimated at $1,604,000 annually without a heat recovery system. If a heat recovery system (boiler) is used the O&M costs could be reduced to between $1,143,000 and $97,000 annually. It is estimated that the payback for this system will be in the first year, considering present costs of disposal.

NAVAL CIVIL ENGINEERING LABORATORY PORT HUENEME CALIFORNIA 93043

METRIC CONVERSION FACTORS

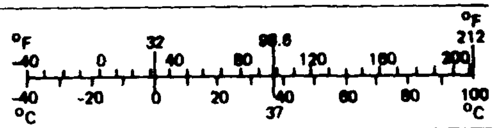
Approximate Conversions to Metric Measures

Symbol	When You Know	Multiply by	To Find	Symbol
		LENGTH		
in	inches	*2.5	centimeters	cm
ft	feet	30	centimeters	cm
yd	yards	0.9	meters	m
mi	miles	1.6	kilometers	km
		AREA		
in^2	square inches	6.5	square centimeters	cm^2
ft^2	square feet	0.09	square meters	m^2
yd^2	square yards	0.8	square meters	m^2
mi^2	square miles	2.6	square kilometers	km^2
	acres	0.4	hectares	ha
		MASS (weight)		
oz	ounces	28	grams	g
lb	pounds	0.45	kilograms	kg
	short tons (2,000 lb)	0.9	tonnes	t
		VOLUME		
tsp	teaspoons	5	milliliters	ml
Tbsp	tablespoons	15	milliliters	ml
fl oz	fluid ounces	30	milliliters	ml
c	cups	0.24	liters	l
pt	pints	0.47	liters	l
qt	quarts	0.95	liters	l
gal	gallons	3.8	liters	l
ft^3	cubic feet	0.03	cubic meters	m^3
yd^3	cubic yards	0.76	cubic meters	m^3
		TEMPERATURE (exact)		
°F	Fahrenheit temperature	5/9 (after subtracting 32)	Celsius temperature	°C

*1 in = 2.54 (exactly). For other exact conversions and more detailed tables, see NBS Misc. Publ. 286, Units of Weights and Measures, Price $2.25, SD Catalog No. C13.10:286.

Approximate Conversions from Metric Measures

Symbol	When You Know	Multiply by	To Find	Symbol
		LENGTH		
mm	millimeters	0.04	inches	in
cm	centimeters	0.4	inches	in
m	meters	3.3	feet	ft
m	meters	1.1	yards	yd
km	kilometers	0.6	miles	mi
		AREA		
cm^2	square centimeters	0.16	square inches	in^2
m^2	square meters	1.2	square yards	yd^2
km^2	square kilometers	0.4	square miles	mi^2
ha	hectares (10,000 m^2)	2.5	acres	
		MASS (weight)		
g	grams	0.035	ounces	oz
kg	kilograms	2.2	pounds	lb
t	tonnes (1,000 kg)	1.1	short tons	
		VOLUME		
ml	milliliters	0.03	fluid ounces	fl oz
l	liters	2.1	pints	pt
l	liters	1.06	quarts	qt
l	liters	0.26	gallons	gal
m^3	cubic meters	35	cubic feet	ft^3
m^3	cubic meters	1.3	cubic yards	yd^3
		TEMPERATURE (exact)		
°C	Celsius temperature	9/5 (then add 32)	Fahrenheit temperature	°F



Unclassified

SECURITY CLASSIFICATION OF THIS PAGE (When Data Entered)

AD-A178 004

REPORT DOCUMENTATION PAGE — READ INSTRUCTIONS BEFORE COMPLETING FORM

1. REPORT NUMBER: TN-1763	2. GOVT ACCESSION NO.: DN666270
3. RECIPIENT'S CATALOG NUMBER:	
4. TITLE (and Subtitle): INITIAL FEASIBILITY STUDY AND BUDGET FOR A HAZARDOUS WASTE INCINERATOR AT PEARL HARBOR NAVAL SHIPYARD	5. TYPE OF REPORT & PERIOD COVERED: Final; Jun 1985 – Sep 1985
	6. PERFORMING ORG. REPORT NUMBER:
7. AUTHOR(s): William Powers, CHMM and Richard Lee, PhD	8. CONTRACT OR GRANT NUMBER(s):
9. PERFORMING ORGANIZATION NAME AND ADDRESS: NAVAL CIVIL ENGINEERING LABORATORY, Port Hueneme, California 93043-5003	10. PROGRAM ELEMENT, PROJECT, TASK AREA & WORK UNIT NUMBERS: 71-011
11. CONTROLLING OFFICE NAME AND ADDRESS: Naval Facilities Engineering Command, Alexandria, Virginia 22332	12. REPORT DATE: January 1987
	13. NUMBER OF PAGES: 51
14. MONITORING AGENCY NAME & ADDRESS (if different from Controlling Office): Pearl Harbor Naval Shipyard, Box 400, Pearl Harbor, HI 96860	15. SECURITY CLASS. (of this report): Unclassified
	15a. DECLASSIFICATION DOWNGRADING SCHEDULE

16. DISTRIBUTION STATEMENT (of this Report)

Approved for public release; distribution unlimited.

17. DISTRIBUTION STATEMENT (of the abstract entered in Block 20, if different from Report)

18. SUPPLEMENTARY NOTES

19. KEY WORDS (Continue on reverse side if necessary and identify by block number)

Hazardous waste, rotary kiln incinerator, incineration, incinerator testing and permitting, economics, combustion technology solid waste, heat recovery, energy recovery, thermal processing, incinerability, destruction and removal efficiencies, Hazardous materials

20. ABSTRACT (Continue on reverse side if necessary and identify by block number)

Spurred by increasing regulatory restrictions, rising costs for transport and disposal, and the lack of suitable hazardous waste disposal sites in Hawaii, Pearl Harbor Naval Shipyard (PHNSY) is considering incineration as a potentially cost-effective and desirable means of disposal. The Naval Civil Engineering Laboratory (NCEL) at Port Hueneme, California, was accordingly tasked with preparation of this initial feasibility study and budget estimate. It is

continued

DD FORM 1473 1 JAN 73 EDITION OF 1 NOV 65 IS OBSOLETE

Unclassified

SECURITY CLASSIFICATION OF THIS PAGE (When Data Entered)

20. Continued

cont'd estimated that PHNSY will require a rotary kiln incinerator capable of handling 4,000 to 8,000 lb/hr of hazardous waste. Capital costs for the physical plant are estimated to range from $2,992,000 to $3,781,000. Total operation and maintenance (O&M) costs are estimated at $1,604,000 annually without a heat recovery system. If a heat recovery system (boiler) is used the O&M costs could be reduced to between $1,143,000 and $97,000 annually. It is estimated that the payback for this system will be in the first year, considering present costs of disposal.

Keywords...

Library Card

Naval Civil Engineering Laboratory
INITIAL FEASIBILITY STUDY AND BUDGET FOR A HAZARDOUS WASTE INCINERATOR AT PEARL HARBOR NAVAL SHIPYARD (Final), by W. Powers, CHMM and R. Lee, PhD

TN-1763 51 pp illus January 1987 Uncalssified

1. Hazardous waste 2. Incinerator testing and permitting I. 71-011

Spurred by increasing regulatory restrictions, rising costs for transport and disposal, and the lack of suitable hazardous waste disposal sites in Hawaii, Pearl Harbor Naval Shipyard (PHNSY) is considering incineration as a potentially cost-effective and desirable means of disposal. The Naval Civil Engineering Laboratory (NCEL) at Port Hueneme, California, was accordingly tasked with preparation of this initial feasibility study and budget estimate. It is estimated that PHNSY will require a rotary kiln incinerator capable of handling 4,000 to 8,000 lb/hr of hazardous waste. Capital costs for the physical plant are estimated to range from $2,992,000 to $3,781,000. Total operation and maintenance (O&M) costs are estimated at $1,604,000 annually without a heat recovery system. If a heat recovery system (boiler) is used the O&M costs could be reduced to between $1,143,000 and $97,000 annually. It is estimated that the payback for this system will be in the first year, considering present costs of disposal.

TABLE OF CONTENTS

BACKGROUND

The Pearl Harbor Naval Shipyard (PHNSY) has been disposing of hazardous wastes by contract (Ref 1 and 2). Since there are no hazardous waste disposal facilities in the State of Hawaii, this requires costly transport to landfills in California and Oregon. Furthermore, the 1984 amendments to the Resource Conservation Recovery Act (RCRA) contain provisions restricting land disposal of some hazardous wastes (Ref 3). Since the Defense Reutilization Marketing Organization (DRMO) presently disposes of Navy hazardous waste, they do not maintain cost records for each activity. Therefore, NCEL developed the following cost estimate for PHNSY. The cost for PHNSY to transport and dispose of 1 ton of hazardous waste to landfills in the continental United States is estimated at $280 (Ref 3). This estimate may prove to be low since a recent preliminary Naval Civil Engineering Laboratory (NCEL) report indicates an average of $604/ton on a Navywide basis. PHNSY is considering construction and operation of a hazardous waste incinerator for these reasons.

Incineration of these wastes could lead to a locally disposable residue if the ash from the incinerator was delisted by the Environmental Protection Agency (EPA). This is obviously beneficial and cost effective. PHNSY is proceeding with the incineration concept since no commercial contractors have expressed an interest in obtaining permits to construct or operate such a facility on Oahu.

This Technical Note is being disseminated to other Navy activities that may be considering incineration as an option for disposing of their hazardous wastes. The information contained herein is useful for evaluating a rotary kiln and other conbustion systems.

NCEL Effort

Because PHNSY has decided to consider installing an incinerator, the shipyard requested NCEL to provide information for developing a MILCON budget. NCEL with PHNSY assistance developed a scope of work to provide the following information (Ref 4):

- Using data provided by the shipyard, identify hazardous wastes generated by PHNSY that can be incinerated, those that cannot be incinerated, and those requiring special testing prior to incineration.

- Identify the most useful type of incinerator based on waste characteristics and quantities.

- Prepare a capital cost estimate for a turn-key incinerator system to be used for developing a preliminary military construction (MILCON) budget.

- Provide basic information on potential off gases and destruction and removal efficiency (DRE) required for incinerating hazardous waste.

- Provide an estimate of capital costs associated with a heat recovery system.

- Provide basic information (including costs) concerning required testing, plans, and permits for compliance with Federal, state, and local regulations.

Actions by PHNSY

PHNSY reviewed the preliminary information in this report and used this information to develop the needed MILCON budget for FY88. In addition, the following was determined by PHNSY staff:

- If not already determined, explore the possible use of the rotary kiln incinerator presently at the Public Works Center (PWC).

- If retrofitting the system is not possible, obtain the necessary permits required to construct and operate a new hazardous waste incinerator.

- Negotiate with incinerator system manufacturers prior to purchasing the incinerator.

COMBUSTIBILITY OF CANDIDATE HAZARDOUS WASTES

Characteristics of PHNSY Hazardous Wastes

Characteristics of PHNSY hazardous wastes, including physical and chemical compositions and quantities generated, are presented in Table 1. Background information in Table 1 is helpful in evaluating waste for incineration. The hazardous wastes generated at PHNSY are identified under commercial name and physical characteristics based upon origin of the hazardous wastes.

Combustibility Classification

Table 2 was prepared using trial test burn data and engineering judgment based on chemical formulas and quantities of compounds present in the wastes. PHNSY hazardous wastes have been classified here under "Good," "Potential," and "Poor" categories, reflecting the incinerability of the wastes using appropriate incineration technology. Potential means the compound could be incinerated by mixing with other compounds or by increasing the temperature of the furnace and increasing residence time. It is possible to blend different wastes or waste and conventional fuels to change a poor or potential category candidate to a good candidate for incineration.

The following selection criteria were used in making combustibility judgments:

Waste Contents	Incinerability
Carbon, hydrogen, and oxygen	Good
Carbon, hydrogen, 30% chlorine and oxygen	Good
Carbon, hydrogen, 30% chlorine, sulfur, Iodine, etc.	Potential
Unknown % of chlorine	Potential
Inorganic compounds	Poor
Compounds containing metals	Poor

Other factors to be considered in evaluating waste for incineration are:

- Moisture content
- Products of incomplete combustion (PICs) in the incinerator off gas
- Inert content
- Heating value/auxiliary fuel requirements
- Physical form
- Known carcinogenicity
- Corrosiveness
- Polychlorinated biphenyls content

Candidate Wastes for Bench Testing

Considering the characteristics of the hazardous wastes produced at PHNSY, most of these wastes can be destroyed by a combustion process under a controlled operating environment. Only the hazardous wastes noted in Table 2 as poor candidates for incineration would need bench/ pilot plant studies. In general, contaminated inorganics like sandblast grits have become detoxified in an incinerator if they achieved the required DRE of 99.99% (Ref 5). However, data would need to be developed under conditions the same as those developed by the specific incinerator to be purchased and used by PHNSY.

This conclusion concerning the combustibility of the "Poor" category of PHNSY hazardous waste can be supported by studying the chemical compositions of the hazardous waste constituents. It is noted that for the solvent categories, flash and boiling points are low compared to the required (RCRA) furnace thermal environment. They are mainly organic compounds and exothermic combustion reactions could be achieved from the combustion of these wastes. However, metals in the waste, such as lead and organotins, would not be destroyed.

INCINERATOR CHARACTERISTICS

Available Options

A survey of commercial incinerators indicates that there are nine types of commonly used incinerators (Ref 6 - 10):

1. Liquid injection
2. Fluidized bed
3. Multiple hearth
4. Rotary kiln
5. Coincineration
6. Starved-air combustor/pyrolysis reactor
7. Catalytic combustor
8. Molten-salt combustor
9. Wet-air oxidation

Performance Standards

The Resource Conservation and Recovery Act (RCRA) requires hazardous waste incinerators to comply with the following performance standards. These items were taken into account in the incineration selection process:

1. An incinerator burning hazardous waste must achieve a destruction and removal efficiency (DRE) of 99.99% for each principal organic hazardous constituent (POHC).

2. An incinerator burning hazardous waste and producing stack emissions of more than 1.8 kg/hr (4 pounds per hour) of hydrogen chloride must be controlled such that the rate of emissions is no greater than the larger of either 1.8 kg/hr or 1% of hydrogen chloride in the stack gas prior to entering any pollution control equipment.

3. An incinerator must not emit particulate matter in excess of 180 mg per dry standard cubic meter (0.08 grain per dry standard cubic foot (scf)) when corrected for the amount of oxygen in the stack gas.

The EPA does not have "design specifications" for incinerators. Equipment that can meet the performance standards should be acceptable.

Incineration Selection Criteria

Incineration is a thermal decomposition process that converts a hazardous waste to a less toxic, less hazardous waste and reduces waste volume. A waste must be combustible for incineration to be a useful means of disposal. In addition to the EPA performance criteria, time, temperature, and turbulence, the "three Ts," are the major criteria for the selection of a hazardous waste incinerator.

Of the nine commercial types of incinerators the first six were considered for this study because of their versatility in accepting a wide range of PHNSY wastes. In matching the different wastes with commercial incineration facilities, the EPA performance standards, the "three Ts," and the following additional criteria were used in the incineration selection process.

Physical Form of the Waste. Incinerators that are able to handle all forms of waste are more versatile and were considered more suitable. Liquids and gases were considered easier to incinerate than other forms of wastes. The following waste forms were considered:

- gas
- liquid
- slurry
- sludge
- solid

Temperature Ranges of the Incinerators. Since some waste containing chlorinated organics would require incineration at PHNSY, those incinerators with temperature ratings in the 2,000°F range were considered most suitable. Temperature ranges considered for evaluation in priority order are as follows:

- 2,000°F
- 1,400-2,000°F
- 700-1,400°F

Off Gases. Off gases from the incineration of specific wastes were also considered. Wastes that generate less toxic off gases that would not create hazardous products of incomplete combustion (PICs) were favored over others. The following waste off gas categories in priority order were established for evaluation purposes:

- Essentially carbon dioxide (CO_2), water vapor and nitrogen

- Halogen acids, sulfur oxides and other volatile species

Ash. The types and components of resultant ash from the incineration of specific hazardous wastes were also taken into consideration. Wastes that would produce an ash that could potentially be "delisted" and disposed of as a nonhazardous waste were favored over those that would generate an ash with toxic or metallic components. The following categories in priority order were used for evaluation purposes:

- Non-toxic

- Non-fusible,

- Fusible

- Metallic

Heating Value of the Waste. Wastes with higher heating values (10,000 Btu/lb) that would require use of less auxiliary fuel were favored over those with lower heating values (5,000 Btu or less). The following categories in priority order were used for rating wastes based on estimated higher heating values:

- 10,000 Btu/lb

- 5,000 to 10,000 Btu/lb

- 5,000 Btu/lb

Comparison of Candidate Incinerators

Of the six types of commercial incinerators compared using the criteria presented, Table 3 indicates that liquid injection, fluidized bed, and rotary kiln incinerators were the most suitable for destroying PHNSY hazardous wastes. These incinerators are described as follows:

Process	Typical Operating Range (°F)	Remarks
Liquid Injection	1,200 to 2,900	This incinerator is suitable for liquid waste directly injected from cans, bulk, or gases. The retention time is in seconds. For loose bulk or containerized solid waste the retention time is in hours.

Fluidized Bed	840 to 1,800	This incinerator allows liquid and gases to be destroyed with a retention time in seconds. Solids destruction requires a retention time in hours. These incinerators are low temperature destruction devices.
Rotary Kiln	1,500 to 2,900	This incinerator is suitable for liquids. Through direct injection it can handle hazardous waste in cans, bulk, or gases. The retention time for liquids is in seconds and for loose bulk or containerized solid waste in hours.

Liquid Injection Incinerator. Virtually any pumpable and combustible liquid hazardous waste (liquid, sludges, slurries, etc.) can be disposed of in a liquid injection incinerator. Liquid wastes are atomized by a burner nozzle, which maintains a proper air/fuel ratio to ensure complete combustion. Atomization is achieved either mechanically by using rotary cup burners or by using a pressure atomization technique. Air or steam atomization can also be used to fire the waste. Even in the case of high heating value wastes, supplemental conventional fuel (gas/oil) should be used to maintain the furnace conditions necessary for the destruction of the waste.

Liquid injection incinerators can be horizontally or vertically fired units (see Figures 1 and 2, respectively). Most of these units operate at temperatures above 2,000°F and at POHC residence times of 0.5 to 2 seconds. These units can achieve a volumetric heat release rate of 2,500 Btu/hr-ft^3 when burning gas or oil. Some of the vortex-type liquid injection incinerators can achieve three to four times this heat release rate.

Most PHNSY-generated liquid hazardous wastes stated in Table 1 can be destroyed by this type of incinerator.

1. Advantages

   - Wide range of liquid wastes can be incinerated.
   - Fast temperature response to compensate changes in feed rate or heating value can be achieved.
   - No moving parts; therefore, maintenance cost is low.

2. Disadvantages

   - Only liquid wastes atomized through a burner can be destroyed.

- Supplemental fuel can be used to assist in destruction of the waste.

- Frequent operation and maintenance problems associated with plugged burner nozzles can be expected.

Fluidized Bed Incinerator. This type of incinerator is quite versatile for disposing of solid hazardous wastes. It consists of a refractory-lined vertical vessel containing inert granular bed material (like sand and fine gravels). Preheated air or gases are blown through a grating, passing through the inert bed material at a rate sufficient to cause the bed to expand to a dense turbulent mass representing a fluid bed. Waste feed either enters above or within the fluidized inert bed with the addition of auxiliary fuel. Combustion of the waste occurs within the bubbling bed. The turbulent bed material promotes high heat transfer and efficient combustion of organics in the waste. Since the hot inert bed is large compared to the injected waste feed, the bed temperatures are uniform and typically in the 900 to 2,300°F range.

A schematic view of a typical process fluidized bed incinerator is shown in Figure 3. High particulate carryover is generally experienced in this type of incinerator; therefore, a particulate collection system is required in addition to a gas scrubber to achieve a clean environment. Basic components of this system include: refractory-lined vessel, fluidizing air supplier (blower), waste feed system, ash removal system, inert bed replenishing device, and air pollution control system.

Primary considerations for the fluidized bed incinerator systems are gas velocity, bed cross section, freeboard height, depth of the bed material, and the type of waste to be incinerated. Generally, the feed has to be processed (shredded, pulverized, and dried) before introducing it into the combustor. The prepared solid feed can be mechanically or pneumatically fed into the vessel. Even in cases of wastes containing high heat content, auxiliary fuel should be fired in the combustor to ensure the necessary destruction temperature within the bed.

1. Advantages

   - Prepared solids, contaminated solid-laden liquids, and even gaseous wastes can be disposed of in this type of incinerator.

   - No moving parts and simple reactor design features are attractive. However, the ash handling and fluidizing air introduction mechanisms are quite involved from a design point of view.

   - Compact combustor design may result in lower equipment cost compared to the other types of combustors.

   - Relatively lower bed temperature - The incinerator produces less oxides of nitrogen, thus, lowering the cost of the pollution control equipment system.

2. Disadvantage

- Feed quality and feed rate will fluctuate but can be tolerated without too much difficulty (because of large amounts of stored heat energy in the bed material).

Rotary Kiln Incinerator. Solids; slurries; sludges; tar residues gaseous liquid and hazardous wastes containing halogenated organics; and chloride, hydrogen, oxygen, nitrogen, and explosive solid wastes have been destroyed in rotary kiln incinerators. The Department of Defense has used such kilns to dispose of chemical warfare agents and munitions.

A rotary kiln is a cylindrical shell lined with firebrick or other refractories and is mounted with its axis at a slight incline from the horizon. The rotational motion of the kiln is used to transport the feed through the kiln length and at the same time achieve active tumbling action, promoting turbulent mixing for efficient combustion of the organics.

A typical industrial unit at Dow Chemical's Midland, Mich., facility is shown in Figure 4. The unit is rated for 65 MBtu/hr. It is used to destroy drummed solids, tar materials, soiled clothing, spill debris, tank sludges, slurries, paints, solvents, and many liquid waste chemicals. The 3M Company uses the same type of rotary kiln for disposal of their hazardous wastes. The kiln is fitted with a hydraulic drive drum feeder and liquid waste injection system. Very little contamination of waste occurs during the handling and feeding of the wastes. Liquid wastes are fired into the furnace while drums containing solid wastes, sludges, slurries are incinerated. Off gas is scrubbed and waste heat recovery can be achieved for a continuous system. Ash-containing inorganics are dumped in the ash pit and hauled to a landfill.

Rotary kiln design features call for a length-to-diameter ratio (L/D) between 2 and 10. Lower L/D ratios result in poor burnout but lower particulate carryover. Rotational speeds are about 1 to 5 ft/min. Both L/D ratio and rotational speed are dependent upon the type of waste destroyed. When a waste requires longer residence time to complete destruction, large L/D ratios along with slower rotational speeds are used. Combustion temperatures range from 1,500 to 2,900°F. A residence time as low as 0.5 second to as high as 60 minutes or more can be achieved.

1. Advantages

- Destroys a variety of solid and liquid wastes.
- Incinerates materials undergoing a melt phase.
- Liquid and solid wastes can be fired together.
- Bulky wastes can be incinerated.
- A variety of feed mechanism designs can be used.
- High turbulence and mixing ensures high DRE.

- Continuous ash removal systems can easily be adapted.
- Waste heat recovery systems can be integrated.
- Retention time can be adjusted to DRE requirements.
- Minimum preparation of feed is required.

2. Disadvantages

- The system capital cost is high.
- The maintenance cost of the refractory lining (because of thermal shock) will be high.
- High particulate loading of the effluent gas has been experienced.
- Significant operating difficulty from rotating seal leakage has been experienced.
- Wastes having high moisture, inorganic salts, inert materials, and high concentration of heavy metals are not appropriate for such incinerators.

Preferred Incinerator Unit

Of the incinerators considered for PHNSY hazardous wastes, identified in Table 1, the rotary kiln is presently the preferred unit since it can handle the largest variety of wastes. This type of incinerator is capable of destroying solids (i.e., sandblast grits containing organotin), slurries, sludges (i.e., degreaser sludge, oily sludge), and liquid (i.e., paints and mixed solvents) hazardous waste simultaneously. Furthermore, most of the liquid wastes can be fired through appropriately designed burners. The lower heating value solvents may be premixed with fuel oil and fired into the kiln as auxiliary fuel for the destruction of solids and sludges. Containerized solids and sludges can also be destroyed and can achieve the desired 99.99% DRE.

The existing rotary kiln at the Public Works Center (PWC) has a capacity of 4,000 lb/hr. The inventory of hazardous wastes indicates a generation rate of wastes at PHNSY of less than 61,650 lb/day, which is less than 3,000 lb/hr. Therefore, if the existing rotary kiln could be operated even at a reduced load of one 8-hour shift a day, it would dispose of the wastes produced each day by PHNSY. It must be noted that it is not desirable to operate any incinerators on a partial schedule basis. The refractory deterioration and other machine-related factors can result in very high maintenance costs when partial firing occurs. PHNSY personnel should determine the operability of the existing unit and obtain information relative to needed retrofitting and cost for using the existing rotary kiln prior to purchasing a new unit.

If retrofitting is not possible, then a new incinerator will be needed. Considering potential future increases in PHNSY hazardous waste generation (i.e., from cleanup of past disposal sites) and possible use

by other military activities on Oahu, a 4,000- to 8000-lb/hr unit may be appropriate. Characteristics of a typical rotary kiln incinerator are provided in Table 4. Cost estimates were based on a typical unit. Table 5 provides a list of rotary kiln manufacturers.

The rotary kiln is lined with a refractory, and repeated start-up and shutdown sequences imposed on the refractory element will cause serious spalling and deterioration of the lining. The kiln should, therefore, be kept hot by continuous firing with auxiliary fuel at a low level heat release rate when hazardous wastes are not being fed into it. To maintain a steady waste input, waste in sufficient quantities should be sought from other nearby activities and a workable waste flow scheme should be developed.

The kiln should be equipped with a variable speed rotational drive and variable flow liquid waste pumps and burners. The kiln should have the provision for excess air combustion. Air injection points should be aligned along the travel path of the kiln. The kiln furnace should be provided with removable tumbler baffle plates so the solid and granular wastes will be agitated along their travel path in the kiln.

A fully automated mechanical feed system should be installed for safe operation of the kiln. In considering incineration of sandblast grit, a dual screw feeder mechanism may be useful.

Heat Recovery Boiler. A heat recovery boiler is appropriate since the incinerator unit will be fired continuously even without hazardous waste to protect the refractory from repeated shocks caused by heating and cooling. Therefore, the flue gas will go into a waste heat recovery boiler unit.

Air Pollution Control (APC). Most solvents are hydrocarbon compounds and off gases will consist mainly of carbon dioxide, water vapor, and nitrogen. These are harmless and could be directly discharged into the environment without any APC. However, off gases containing hydrogen chloride and other noxious elements have to be scrubbed with reagent solutions before releasing to the environment. Acceptable gas cleaning efficiency can be achieved with a high energy venturi scrubber. An effective mist eliminator must accompany the scrubber. The scrubber may be designed to clean both particulates and gaseous pollutants or just the former if a particulate removal device is installed in the gas train. A pressure drop of up to 10 inches of water column across the venturi may be required to achieve effective cleaning of some gaseous pollutants. An alkaline scrubbing solution should be used when acid gases such as hydrogen chloride, hydrogen sulfide, hydrogen cyanide, or sulfur oxide are to be removed. Also performance/design specifications should be maintained for particulates and hydrogen chloride.

CAPITAL COSTS

Direct Capital Costs (DCC)

The physical plant for which the costs indicated in Table 6 were based upon consists of a rotary kiln (primary chamber) capable of handling 4,000 to 8,000 pounds of hazardous waste per hour. The kiln has feed

systems for solid and liquid wastes and is equipped with an after burner and a fabric filter baghouse for air pollution control. A waste heat boiler is included within the plant for heat recovery.

The physical plant also includes a 100-foot stack and a prewired indoor instrument control panel with a pre-engineered building for a control room. A receiving/staging area (1,000 ft^2.) with a metal roof, concrete bermed slab floor, compartments for storing incompatible wastes, and fencing is also included within the physical plant.

The capital cost estimate for the physical plant was prepared by NCEL using data from manufacturers, consultants, and the U.S. Army (Ref 11 through 19). This cost estimate includes both direct and indirect capital costs (Table 6). Total capital costs for this project are estimated at between $2,992,000 and $3,781,000 for a rotary kiln incinerator unit capable of destroying PHNSY hazardous wastes.

Direct capital costs include all system components and ancillary equipment. Direct capital costs are provided in Table 6 and are based on data gathered from equipment manufacturers and engineering publications. These costs are estimated to range from $1,380,000 to $1,741,000 for a rotary kiln incinerator capable of handling PHNSY hazardous wastes. These costs are based on a 4,000- to 8,000-pph system with feed mechanisms capable of handling both solids and liquids.

Indirect Capital Costs (ICC)

Indirect capital costs include all costs incurred for placing the incinerator in operation, such as construction; erection; engineering design; testing; permits; plans; environmental impact reports; startup and training for two operators, spare parts; free on board (f.o.b.) Honolulu, Hawaii; and a staging/receiving area. Indirect capital costs arc estimated to range from $1,340,000 to 1,696,000 (Table 6).

OPERATION AND MAINTENANCE (O&M) COSTS

Operations Costs

In general, O&M costs are dependent upon labor, the amount of auxiliary fuel required, frequency of replacing the refractory lining, amount of steam produced, and cost of ash disposal. The service life of the rotary kiln is estimated at 15 years and may be extended if proper maintenance is provided. Extending the incinerator's useful life to the maximum extent requires constant 24 hr/day firing to protect the refractory lining from thermal shock. In addition, a benefit can be obtained by using a waste heat recovery boiler (HRB) to generate steam.

Estimates of O&M costs were based on two scenarios each firing the same 50/50 blend of auxiliary fuel and hazardous waste at a feed rate of 6,000 lb/hr. In actuality, the ratio of fuel to waste will vary with the shift, need for auxiliary fuel, and characteristics of the waste, but it should average 50/50. Scenario A assumes a worst-case situation, firing auxiliary fuel and waste having no heat value. In this instance, 100% of the heat value is derived from the auxiliary fuel (hazardous waste heat value (HV) = 0). Scenario B assumes firing auxiliary fuel

and hazardous waste having a 5,000- heat value. The O&M cost based on Scenario A is $1,143,000 (Table 7). These costs can be reduced to $97,000 annually by firing auxiliary fuel and waste having a high heat value (5,000 Btu/lb) (Table 7). Both scenarios are based on firing 24 hr/day, 329 days/yr, assuming 10% downtime.

The following information provides cost factors, assumptions, and rationales used in developing the O&M cost estimate provided in Table 7.

Auxiliary Fuel. The cost of auxiliary fuel is based on the incinerator requiring 13 MBtu/hr to ensure complete combustion. A drum of No. 2 fuel oil contains 42 gallons and provides 5.8 MBtu (Ref 20). Therefore, 2.24 drums of No. 2 fuel are required per hour of operation. This converts to 17,687 barrels or 742,854 gallons of fuel per year. Assuming $1.25 per gallon, fuel costs of $929,000/yr can be expected (Table 7). Fuel cost depends on the actual hours of operation and the cost for auxiliary fuel.

Under operating conditions, further efficiencies could be obtained by properly adjusting auxiliary fuel/waste ratios when high heat value wastes are fired (i.e., contaminated JP-5). This adjustment can minimize auxiliary fuel consumption resulting in a significant saving. Adjusting fuel/waste ratios is highly variable and may not be practical under field conditions. The exact ratios and heat value (Btu) of the mixture being fired (auxiliary fuel/waste) must be known. This was not taken into consideration for estimating O&M costs.

Scenario B provides a significantly lower O&M cost of $97,000 annually. This reflects projected benefits from increased steam generation and firing auxiliary fuel with waste having a heat value of 5,000 Btu/lb.

Electricity. The cost for electricity is based on consumption of 100 kW-hr for continuous firing. The cost per kW/hr is assumed to be $0.08 (Ref 21). The estimated total cost for electricity is $63,000 annually (100kW x 24 hrs x 329 days x $0.08 = $63,168, rounded to $63,000) (Table 7).

Water. It is estimated that water will be consumed at a rate of 1,300 gal/hr. The cost of water is assumed to be $0.84/1,000 gal (Ref 21). The annual cost is estimated at $9,000 (1,300 gal x 24 hr x 329 days ÷ 1,000 x $0.84 = $8,623, rounded to $9,000) (Table 7).

Wastewater. Wastewater from the rotary kiln incinerator will require neutralization prior to disposal in the local sewage treatment plant (STP). It is estimated that chemicals for neutralization of the effluent will be a nominal $1,000 annually. Considering all the water consumed will be disposed through the STP, about 11.4 million gallons per year would require disposal. The annual cost for wastewater treatment and disposal is estimated at $11,000 annually, assuming a treatment and disposal cost of $1/1,000 gal (1,300 gal x 24 hrs x 329 days ÷ 1,000 x $1 + $1,000 = $11,265 rounded to $11,000) (Ref 21) (Table 7).

Maintenance Costs

Maintenance, Repair, and Inspection. These items are of utmost importance to the overall life of the incinerator. The need to repair bearings, seals, and refractory lining can be lessened by inspection and keeping to manufacturer-recommended maintenance schedules. It is estimated that $133,000/yr will be required for maintenance, repair, and inspection (Table 7). This estimate includes $33,000/yr to be set aside for replacing the refractory lining every third year (the estimated replacement cost is $100,000.)

Ash Disposal. It is assumed that the ash (fly ash and residual ash can be disposed of as a nonhazardous waste in a solid waste (Class II) landfill. This type of disposal depends on EPA delisting the ash. Considering both Scenarios A and B, it is estimated that the same amount, about 25% of the throughput, will result in an ash requiring disposal. This will result in 6,570 tons of ash requiring disposal annually at an estimated cost of $263,000 (6,570 tons of ash/yr x $40/ton = $262,800, rounded to $263,000) (Table 7). Ash disposal requirements can vary since the throughput will be hazardous waste of varying forms (i.e., solid, semisolid, liquid) with varying heat values. The cost per ton for disposal of the ash in a local nonhazardous waste landfill (Class II) is estimated at $40.

Labor

At a minimum, two persons will be required to operate the rotary kiln on an 8-hour basis. Therefore, around-the-clock, 24-hour operation will require six persons for three shifts a day. The estimated $120,000 for wage-grade furnace or boiler operators includes wages, benefits, and overhead (Table 7).

Burden

The burden is estimated at 5% of the subtotal O&M costs or about $76,000 annually (Table 7).

Benefit for Steam

Considering the generation of 7,274 lb/hr of steam from auxiliary fuel, a benefit of $461,000 is estimated annually for Scenario A ($574,355 - $113,474 = $460,881, rounded to $461,000). This provides an adjusted O&M cost of $97,000.

ENERGY BALANCE AND STEAM GENERATION COST BENEFIT

Energy Balance

A typical rotary kiln system longitudinal section is depicted in Figure 5. A matching temperature profile is depicted in Figure 6. As illustrated in Figure 7, industrial waste incineration produces a significant quantity of energy which can be recovered and used to produce steam.

Waste heat recovery boilers (HRBs) for incineration applications may be designed for either maximum steam production or maximum availability. Experience with incineration systems processing a wide variety of waste materials has shown that simultaneous achievement of both goals is not possible. HRBs designed to maximize steam production have suffered from severe maintenance problems, such as corrosion and slagging on boiler surfaces and plugging of boiler tube bundles.

A schematic of a rotary kiln system energy balance is depicted in Figure 8. The rotary kiln is the principal combustion unit. Waste is fed through the upper end of the kiln so that a high combustion efficiency in both the gas and solid phases is achieved. Mixing and combustion can be controlled by varying the speed of the rotating drum (kiln). A temperature of 2,300 to 2,400°F is maintained at the lower half of the kiln (Figure 8, Point 1). The energy loss at the kiln is assumed to be 5%. One wastewater lance with assumed 6% energy loss is built into each of the sides of the mixing chamber for injecting oil-contaminated wastewater. The average temperature of the flue gas entering the mixing chamber is 2,000 to 2,200°F (Figure 8, Point 2). A standby waste oil burner is provided to maintain a minimum temperature of 1,800°F. To guarantee that the flue gases are completely combusted, high-velocity secondary air is injected at the secondary combustion chamber. The resultant flue gas temperature drops to 1,550 to 1,650°F (Figure 8, Point 3). Tertiary air is injected at the top of the secondary combustion chamber thereby lowering the temperature at the boiler inlet to 1,300 to 1,450°F (Figure 8, Point 4). Finally, the flue gases (1,400°F) flow through the HRB (Figure 8, Point 5).

Assuming that the efficiency of the boiler is 65%, 65% of the energy of the flue gases entering the boiler (Figure 8, Point 5) will be effectively used to generate steam. This takes into account a 2% boiler loss from boiler blowdown and 33% stack loss. The total steam (M_{stm}) to be generated from the HRB can be calculated from the energy balance of the incineration system as follows:

<u>(Energy at Point 1)</u>

$$E_1 \text{ (MBtu/hr} = (M_{ws} \times H_v + F_1 \times 10^6) \times (1 - 5\%) \tag{1}$$

<u>(Energy at Point 2)</u>

$$E_2\text{(MBtu/hr)} = (E_1 + F_2 \times 10^6) \times (1 - 5\%) \tag{2}$$

<u>(Energy at Point 5)</u>

$$E_5 \text{ (MBtu/hr)} = E_2 \times (1 - 5\%) \tag{3}$$

where: M_{ws} = waste feed rate to incinerator, lb/hr

H_v = heat value of waste, MBtu/lb

F_1 = fuel input of auxiliary-fired burner at the kiln, MBtu/lb

F_2 = fuel input of auxiliary-fired burner at the secondary combustion chamber, MBtu/lb

As a general rule, 1,000 Btu is required to generate 1 pound of moderate superheated steam. Therefore, the quantity of steam to be generated will be:

$$M_{stm}\ (\text{lb/hr}) = (E_5 \times 65\%)/1{,}000 \tag{4}$$

Combining Equations 1, 2, 3 and 4 provides:

$$M_{stm}(\text{lb/hr}) = \frac{(M_{ws} \times H_v + F_1 \times 10^6)(95\% + F_2 \times 10^6)}{1{,}000}$$

$$\cdot\ (94\%)(95\%)(65\%)$$

Equation 5, is a function of waste feed rate, heat value of the waste, and fuel rates of the auxiliary-fired burners. Therefore, heat loss rates of the incinerator (i.e., 72% is burned at the rotary kiln and 28% at the secondary combustion chamber) are 9.36 MBtu/hr for F_1 and 3.64 MBtu/hr for F_2 (Figure 8).

Table 8 and Figure 7 represent the total steam that can be generated at different waste feed rates and heat values. When the heat value of the waste is zero (i.e., Scenario A) there will be 7,274 pounds of steam per hour generated from energy of the auxiliary fuel alone. This represents about 45% of the total heat loss from the incinerator. If the waste incinerated has a heat value of 5,000 Btu/lb with a feed rate of 6,000 lb/hr, there will be about 23,000 lb/hr of steam generated (Table 8).

Cost Benefit

Table 9 and Figure 9 indicate the potential annual saving (considering the value of steam at $10/MBtu) that can result from the steam generated by the HRB (i.e., assuming 10% downtime annually).

O&M costs associated with steam generation and heat recovery are provided in Table 10. The net saving or benefit associated with steam generation, considering firing with auxiliary fuel and waste having no heat value (Scenario A), is estimated at $461,000 annually. This savings, or benefit is on the conservative side since the Btu value of waste with 5,000 Btu/lb heat value in a 50/50 ratio at a rate of 6,000 lbs/hr could potentially yield a saving or benefit of $1,507,000 annually (Scenario B) (Tables 8 and 9).

The actual O&M costs for heat recovery are very difficult to estimate without knowing the actual system to be built. However, it is reasonable to assume that these costs will be in the vicinity of $2/1,000 lbs of steam generated. This cost is reflected in the saving benefit calculations for steam (Table 10).

TESTS AND PERMITS

Prior to constructing and operating a hazardous waste incinerator, tests will be required and permits have to be obtained from Federal, State, and local regulatory agencies having jurisdiction over the facility (Ref 22, 23, and 24). Since each organization requires different information in very different formats, it is suggested that preapplication meetings be held with each agency prior to preparing or submitting permit applications. This procedure will expedite data gathering efforts and allow the project to obtain permits within the least amount of time possible. General information concerning the major permits required and the types of plans prepared is provided herein. Table 11 lists the companies capable of providing the required sampling, analyses, bench tests, trial burn, permits, and environmental impact reports and preparing the permit applications.

Tests

Bench Tests. Bench tests of PHNSY-generated wastes should be performed to define and confirm principal organic hazardous constituents (POHCs) prior to field testing the incinerator and select the appropriate POHCs for specification in the permit. This information should be determined to delineate conditions of operation required to prevent formation of hazardous products of incomplete combustion (PICs). Laboratory tests will determine overall incinerability and identify problem wastes and general incinerator parameters. Bench testing is highly recommended (especially for compounds containing metals) and can be accomplished by the EPA's Combustion Research Facility in Arkansas using NCEL as the point of contact (Ref 25).

Trial Burn. The actual cost and extent of testing vary considerably. This cost depends on EPA review of the permit data, number and volume of hazardous waste streams, and POHCs identified by EPA as requiring testing. In addition, a trial burn exemption can be requested and if obtained could provide a considerable saving. However, in light of current EPA policies, a trial burn will most likely be required for all new incinerator facilities. The trial burn plan assures EPA that the trial burn will provide sufficient technical data to demonstrate the incinerator's destruction and removal efficiency (DRE) and predict expected emissions. The trial burn determines whether the incinerator can meet the required performance standards established by EPA in the permit and identifies operating conditions necessary to maintain these standards.

Delisting Tests. PHNSY can petition EPA to delist the resultant incinerator ash. If granted, the ash would no longer be considered a hazardous waste for purposes of RCRA. The ash could then be disposed of in a solid waste landfill approved for nonhazardous waste. Testing of the ash would be required prior to delisting and could be accomplished by contract with a local laboratory certified by EPA to conduct the testing. Test results would need to indicate the ash did not meet the RCRA hazardous waste definition (40 CFR part 261).

Federal Permits

Federal permits required for a hazardous waste incinerator in Hawaii are administered by the EPA, region IX, San Francisco, Calif.

Resource Conservation and Recovery Act (RCRA). Owners and operators of hazardous waste incinerators are required to obtain hazardous waste permits administered under RCRA (Ref 26). Each facility treating, storing, or disposing of hazardous waste must apply for and receive these permits. The RCRA permit is divided into two parts, known as part A and part B. Owners and future operators of new incinerator facilities must submit both part A and B applications to EPA at least 180 days before construction is expected to begin. EPA standards for hazardous waste incinerators (40 CFR 264-270) specify information required to complete application forms.

Part A consists of general information and a hazardous waste application form and is required to obtain interim status under RCRA.

Part B must be completed to receive a permit and contains the balance of the information necessary to fully evaluate the facility's performance. This information will be used by EPA to reach a decision concerning issuance of the permit. This part of the permit contains the following information.

- Waste sampling and analysis information
- Proposed incinerator operating conditions
- Facility engineering description
- Incinerator performance data
- Trial burn plan and protocol

Permit preparation is a complex process and should be handled by an experienced consultant (i.e., Table 11). A flow diagram for preparing an RCRA permit application is provided in Figure 10. The major plans and information to be developed and submitted with the permit application follows:

1. Trial Burn Plan. The purpose of the trial burn plan is to determine the DRE of incineration as a method of destroying PHNSY-generated hazardous waste. This plan provides information on expected off gases and is used in determining actual operating parameters of the incineration unit. Although RCRA regulations authorize EPA to grant exemptions from conducting a trial burn, it is current EPA policy to require trial burns for all new incinerators.

As part of the trial burn plan a preliminary trial burn protocol is required. This information will familiarize the permit reviewer with the general nature and range of variables for the planned trial burn. Information on expected pollutant emission rates, source classification, and a proposed schedule of tasks to be completed must be provided. The trial burn plan should include the following information:

- Engineering description of the incinerator

- Test monitoring procedures

- Test schedule and protocol

2. Facility Engineering Description. As part of the permit submission, EPA requires a description of the facility, a site map, and design and performance criteria information including the following:

- Facility design criteria

- Incinerator design criteria and performance standards

- Facility dimensions

- Capacity

- Nozzle and burner design/stoker mechanism design

- Location of temperature and pressure indicator devices and piping and instrumentation drawings (P&ID)

- Auxiliary fuel system

- Air pollution control system

- Stack gas monitoring system

- Operation and maintenance procedures

3. Sampling and Analysis Plan (Waste Characterization). The objective of the sampling and analysis plan is to provide a detailed description of waste sampling, analyses and monitoring to be performed prior to and during the trial burn. Specific areas to be addressed within this document include the following:

- Testing equipment

- Flue gas testing procedures

- Process liquids (i.e., scrubber solutions, quench tank water, and boiler feed water) and solid waste characterization methods and results

- Information relative to conducting both detailed waste analyses and periodic waste analyses to verify waste feed composition

- Procedures for quality control monitoring of all sampling and analyses performed

Equipment calibration procedures, field testing, analytical data recording, and results are to be provided within this plan. This information will allow the permit reviewer to designate the POHCs.

4. Emergency Procedures Plan (Safety Plan). The emergency procedures plan describes procedures for minimizing hazards. In particular, this plan addresses four major areas:

- Emergency response procedures
- Facility security
- General field safety procedures
- Specific field safety procedures relative to material handling and incinerator testing

This plan addresses training requirements, personnel responsibilities, testing safety, decontamination, symptoms of exposure, and site-specific precautions.

The emergency procedures plan must be implemented in accordance with applicable Federal, State, local requirements and Navy policies. This plan must be revised based on changes in field conditions and additional information received during the trial burn.

5. General Facilities Plans. Since general RCRA requirements apply to all hazardous waste treatment, storage, and disposal facilities, including incinerators, some overlap occurs in the information required by EPA. Therefore, the following operational plans and information must also be provided:

- Facility location/topographic map
- Waste analysis plan
- Security plan
- Inspection schedule
- Emergency preparedness and spill prevention plan
- Spill contingency plan
- Traffic plan
- Training plan
- Final facility closure plan (permanent closure)

As previously stated, some of the information required for a permit is duplicative but must be provided within each specific plan requiring it. In addition, other existing activity plans (i.e., hazardous waste management plan; spill prevention, control, and countermeasures plan (SPCC); and spill contingency (SC) plan) will need updating to accommodate the hazardous waste incinerator facility.

Clean Water Act. Provisions of the Clean Water Act authorize EPA to issue effluent discharge permits under the National Pollutant Discharge Elimination System (NPDES). Under an existing NPDES permit the Pearl Harbor sewage treatment plant (STP) is allowed to discharge its effluent to local sewers after treatment. However, it must meet the predetermined permit standards, and at any time local regulatory authorities may revoke the Navy's discharge privileges for a number of reasons, including exceeding STP capacity limits or the promulgation of more stringent regulations. Thus, operations discharging to the STP should be prepared to meet all current and future requirements including those relating to toxic and hazardous effluents. Wastewater discharged from an incinerator ash quench tank or wet scrubber would be considered new sources and each would require an NPDES permit. However, PHNSY should first try to obtain a modification of the existing permit.

An NPDES permit consists of three parts. Part I contains effluent limitations and monitoring requirements. Part II provides the management requirements and general permit conditions. Part III specifies allowable limits for toxic pollutants. The current trend within EPA is to place heavy emphasis on control of toxic and hazardous discharges. If the PHNSY incinerator is properly operated to achieve the required DRE of 99.99 percent and the scrubber effluent is properly neutralized prior to discharge, it would not be anticipated to contain toxic or hazardous components. If scrubber effluent can thus be discharged to the STP, no major obstacles to obtaining an NPDES permit should arise.

National Environmental Policy Act (NEPA). Depending on the perceived impacts, either a negative declaration or a full-scale environmental impact report (EIR) can be required by regulatory agencies. The authority for an EIR is contained in the National Environmental Policy Act. Facilities constructed using Federal funds must comply with the NEPA, and local authorities are required to pass judgment on the adequacy of the report, therefore, playing an important role in rating its comprehensiveness and thoroughness.

Depending on the extent of public interest and regulatory agency review, an environmental impact report can cost between $75,000 and $150,000 (or more). The companies shown earlier in Table 11 are also capable of providing the necessary testing, permit preparation, and environmental impact reports required by the NEPA and other laws.

State of Hawaii Permits

In accordance with the Clean Air Act administered by the State of Hawaii, Department of Health Services (Administrative Rules, Title 11, Chapter 60, Air Pollution Control Rule 11-60), construction of an incinerator is not authorized without approval of two permit applications. The first permit application required is for construction and the second is for operation (Ref 27 and 28).

Delays can be caused by submitting incomplete applications; therefore, the State Department of Health, Air and Solid Waste Permit Section, Environmental Permits Branch, and the Naval Facilities Engineering Command, Pacific Division, (PACNAVFAC) Environmental Branch (Code 114), should be contacted prior to preparing the application submittal package.

Figure 11 provides a diagram of the State of Hawaii permit application procedures. For the most part, data obtained for Federal permits may be used for test data submitted to the State. The State of Hawaii will need the following information:

- Equipment descriptions
- Location drawings and process flow diagrams
- Incinerator performance data
- Air pollution emission data

In addition, information relative to determining public interest and environmental impact for the project must also be provided to the State. This information includes:

- The probable impact of the proposed project
- Probable adverse environmental effects that cannot be avoided
- Alternatives to the proposed project
- Relationship between local short-term uses of the environment and maintenance of long-term productivity
- Irreversible and irretrievable commitments of resources

County of Honolulu Permits

The major county permit to be issued is the Conditional Use Permit (CUP). Other county permits relative to building and safety and construction code requirements may be required for this project.

The issuance of a new CUP or modification of an existing CUP is dependent upon the compatibility of the project with existing and potential surrounding land uses. This includes protection of environmental resources and the preservation of health, safety, and public welfare. The county's planning department reviews, processes, and issues CUPs for waste management facilities. This process requires a public hearing prior to approval.

RECOMMENDATIONS

1. If it has not been done, PHNSY should explore the possible rehabilitation, retrofit, and use of the Public Works Center (PWC) incinerator.

2. If rehabilitation and retrofitting are not practical (as is probably the case) then a new incinerator should be purchased.

3. If a new incinerator is required, then PHNSY should thoroughly review the preliminary data provided within this report and proceed with incorporating this information into the MILCON budget for FY88.

4. The possibility of aggregating wastes from other military activities should be explored. This is recommended since the larger the waste throughput, the more economical the system will be. The incinerator can be made operational for the maximum percentage of time, thus reducing startup and maintenance costs.

5. PHNSY should further evaluate the potential benefits obtained by using a heat recovery system (waste heat boiler). Since destruction of PHNSY waste will require almost continuous use of auxiliary fuel to obtain the required DRE, fuel conservation will be a critical concern.

6. The incinerator should be located at a site readily accessible to utility input and output lines (i.e., electrical, water, steam) to minimize utility hookup costs.

7. PHNSY should project public interest in the project and adjust the schedule and cost estimate accordingly. If a high degree of public interest is encountered, implementation may be delayed 2 years, adding an estimated $250,000 to $500,000 to the overall project costs.

8. A pre-permit application meeting should be held with EPA, State, and county regulatory agencies before assembling the necessary permit data. The PACNAVFAC Environmental Branch representative should be requested to participate in these meetings.

9. PHNSY should initially show cause and request an exemption from conducting a trial burn, thereby providing a saving if the request is granted.

10. It is estimated that a 4,000- to 8,000-lb/hr turnkey rotary kiln incinerator for incinerating PHNSY hazardous waste will cost between $2.99 and $3.78 million depending on the options selected and the regulatory agency requirements. It is therefore recommended that PHNSY seek PACDIV assistance in negotiating with incinerator system manufacturers and regulatory agencies prior to purchasing a specific incinerator unit.

11. Since the entire process of obtaining permits for a hazardous waste incinerator and conducting the necessary testing is complex, it is recommended that PACDIV provide consultation and assistance with permitting aspects of this project. In addition, the services of the EPA/Hazardous Waste Engineering Research Laboratory (HWERL), Cincinnati, Ohio, and the EPA Combustion Research Facility in Arkansas can be arranged through an established NCEL contact at PACDIV's request.

REFERENCES

1. Pearl Harbor Naval Shipyard, Code 308. NAVSHIPYD Pearl Instruction 5090.1: Hazardous waste management plan for Pearl Harbor Naval Shipyard, Pearl Harbor, Hawaii.

2. Meeting between R.M. Roberts, NCEL, Code L71, and NAVSHIPYD Pearl Harbor, (Code 308), 14 Jun 1985.

3. Norman Beecher, editor. Hazardous waste and hazardous materials. New York, N.Y., Mary Ann Liebert Inc., vol. 2, no. 1.

4. NCEL Message 180830Z of Jun 1985, to NAVSHIPYD Pearl Harbor, HI, Subject: Development of budget for MCON, FY-88.

5. David Taylor Naval Ship Research and Development Center. DTNSRDC SME-84/33: Rotary kiln detoxification of organotin-contaminated abrasive, by C.M. Adema. Bethesda, MD., Dec 1984.

6. Environmental Protection Agency. EPA/530/SW-141: Incineration in hazardous waste management. Hazardous Waste Environmental Research Laboratory, Cincinnati, 1975.

7. Noyes Data Corp. Incineration of industrial hazardous waste and sludges, by M. Sittig. Park Ridge, N.J., 1979.

8. R. Holzhauer. "Fluidized-bed combustion systems," Plant Engineering, vol. 38, no. 1, Jan 1985.

9. Energy and Environmental Research Corp. Technologies for the incineration of hazardous waste, by W.R. Seeker. Irvine, Calif., 1985.

10. Combustion technology for incinerating wastes from Air Force industrial processes, by W.M. Shaub, and W. Tsang. Washington, D.C., Feb 1984.

11. State of California, Department of Health Services. Alternative technologies for recycling and treatment of hazardous waste, Second biennial report. Sacramento, Calif., Jul 1984.

12. CE-Raymond, Combustion Engineering Inc. Bulletin 815: Rotary kiln incinerator system. Houston, Tex.

13. S. Kleinhentz. Telephone conversation, Systech Corp. and B. Powers, NCEL, Code L71, 10 Jul 1985, Subject: Cost for plans, tests, permits and environmental impact report for Lebec, Calif., rotary kiln incinerator facility.

14. G. Hunt. Telephone conversation, Environmental Research and Technology and B. Powers, NCEL, Code L71, 5 Jul 1985, Subj: Cost comparisons for tests, plans, permits and environmental impact report for rotary kiln incinerators.

15. Matson Steamship Line. Telephone conversation, B. Powers, NCEL, Code L71, 5 Jul 1985, Subj: Shipping costs f.o.b. Honolulu, Hawaii.

16. CE-Raymond, Combustion Engineering Inc. R. Mahon ltr. of 1 Jul 1985, Subj: Rotary kiln incinerator.

17. M. Star. "Cost estimating for hazardous waste incineration," Pollution Engineering, vol XVII, no. 4, Apr 1985, pp21-24.

18. U.S. Army Toxic and Hazardous Materials Agency. Contract Report: Economic evaluation of alternative incineration options for explosives contaminated soils, final technical report, Roy F.Weston Inc., Westchester, Pa., Dec 1984.

19. Environmental Elements Corp. M.J. Girovich ltr of 7 August 1985, Subj: Costs for a rotary kiln incinerator system.

20. NAVFAC ltr. L73/726 Ser. 3900 of 16 May 1985, Subj: Utilities providing services to Navy shore facilities.

21. National Petroleum Institute for Petroleum and Energy Research. NIPER 136: Heating oils 1985, by E.M. Shelton and C.L. Dickson. Bartletsville, Okla., p. 8414.

22. Shirco Inc. Development of an industrial waste incinerator system: Pilot testing through full scale operation, by M. Hill. Dallas, Tex., 1984.

23. Systech Corp. Test protocol for supplemental fuels test burn Marquette cement kiln at Ogelsby, IL, by G. Smith. Xenia, Ohio, Dec 1981.

24. C.E. Raymond. Telephone conversation, B. Powers, NCEL, Code L71, 9 Sep 1985.

25. Environmental Protection Agency/C.C. Lee ltr of 13 Aug 1985, Subj: Test of Pearl Harbor waste at EPA Combustion Research Facility. Hazardous Waste Engineering Research Laboratory.

26. Environmental Protection Agency. Applications for a hazardous waste permit, Consolidated Permits Program. Cincinnati, Ohio, Jun 1980.

27. State of Hawaii, Department of Health. Administrative Rules, Title II, Chapter 59: Ambient air quality standards. Honolulu, Hawaii, 29 Nov 1982.

28. State of Hawaii, Department of Health. Administrative Rules, Title II, Chapter 60: Air pollution control with application forms. Honolulu, Hawaii, 29 Nov 1982.

29. Environmental Research and Technology. ERT handbook on permitting under the Resource Conservation and Recovery Act, first edition, by J. Cesler, Concord, Mass., Nov 1984.

Table 1. Physical and Chemical Composition Data for Pearl Harbor Naval Shipyard Hazardous Waste Inventory

Principal Material	Annual Waste (gal)	Quantity of Generated (lb/day)	Characteristics of Virgin Material[a]
Gamlen CW	1,200,000	19,726	• 80% aliphatic hydrocarbon • sp. gr: 0.8267 • flash pt: 190°F • boiling pt: 360°F
Sandblasting grit with organotin[b]	18,630		• solid (see Ref 4)
Walnut shell with organotin[c]	18,630		• solid (see Ref 4)
Paint	109,000	1,792	• liquid, viscous, or solid
Cooling oil/cutting oil	55,000	979	• liquid with organic compound
Oily sludge	45,000	740	• **solid/liquid (39.4% water, 47.9% oil, .3% ash, 4.4% unknown**
Solvent reclamation residue	72		• sludge, solid/ liquid
Freon 113	20,700	745.9	• refrigerant, liquid • boiling pt: 114.4°F • sp. gr.: 1.579
Corrosion/rust preventive (Tectyl)	20,000	329.0	• liquid protective coating
Dry cleaning solvent	7,650	136.24	• solvent, degreaser • boiling pt: 132-137°F • flash pt: 100-165°F
Brulin's Scotch Cleaner	7,200	118.0	• liquid degreaser (25% water, 40% petroleum, 20% anionic, 10% butoxyethanol, 5% builder)

Table 1. (Continued)

Principal Material	Annual Waste (gal)	Quantity of Generated (lb/day)	Characteristics of Virgin Material[a]
Ethyl cellosolve monoethyl	6,560	116.8	• vapor pressure: 3.8 mm Hg • sp. gr.: 0.93 • boiling pt: 275°F • flash pt: 100-165°F
Special hull treatment	5,000	80	• solvent, metallic base
Perchloroethylene	3,700	65.9	• solvent, degreaser • boiling pt: mo.wt. 482-489.2°F • sp. gr: 1.625 • vapor pressure: 19 mm Hg @ 68°F
Mineral spirit grade 1	3,025	51.4	• cleaner, solvent • boiling pt: 157-199°F
Mixed solvents	3,000	53.4	• solvent, liquid
Hydraulic fluid with water glycol or phosphate ester	4,000	65.8	• organic compound
Methyl isobutyl ketone	1,450	25.8	• lacquer solvent, dewaxing agent • boiling pt: 240.4°F • flash pt: 75°F • solubility: 2% in water
Cleaning compound	1,400	23.0	• solvent
Coal tar epoxy	1,000	16.4	• viscous or liquid
Degreaser sludge	1,000	17.8	• solid/liquid
Carbon-removing compound	1,000	16.4	• solvent, degreasing agent

Table 1. (Continued)

Principal Material	Annual Waste (gal)	Quantity of Generated (lb/day)	Characteristics of Virgin Material[a]
Acetone	200	3.56	• processing solvent • boiling pt: 133.7°F • heat of combustion: 427.92 kcal/g
Chlorobenzene	200	3.3	• carcinogenic • sp. gr: 1.106 • boiling pt: 270°F
1,1,1 trichloroethane	192	3.4	• solvent, degreaser, • boiling pt: 165°F • vapor pressure: 100 mm Hg @ 68°F • sp. gr.: 1.35 • heat of combustion: 1.74 kcal/g
Tert-butyl alcohol	10	10	• dehydrating agent • boiling pt: 180°F • flash pt: 95-115°F • heat of combustion: 639.53 kcal/g

Notes:

[a]Flash point is defined as the lowest temperature at which fuel will vaporize to a combustible mixture.

[b]Organotin sandblasting grit and walnut shells are problem wastes but are not considered hazardous wastes under RCRA. However, the volume and toxicity of this waste are reduced by incineration (Ref 4). It must be emphasized that the RCRA "Mixing Rule" states that any waste with hazardous waste results in the mixture being considered hazardous waste (Ref 25).

[c]Constituents may be classified.

Table 2. Combustibility Classification[a]

Waste Description	Candidate for Incineration[b]			Preferred Incinerator		
	Good	Potential	Poor	Liquid Injection Incinerator	Rotary Kiln	Fluidized Bed
Methyl isobutyl ketone	X			X	X	
Mineral spirit, grade 1	X			X	X	
Ethyl cellosolve	X			X	X	
Acetone	X			X	X	
Tert-butyl alcohol	X			X	X	
Dry cleaning solvent	X			X	X	
1,1,1 trichloro-ethane	X			X	X	
Perchloroethylene	X			X	X	
Freon 113[c]						
Oily sludge	X				X	X
Solvent reclamation residue		X			X	X
Paint (liquid) (solid)[d]	X				X	
Brulin's Scotch Cleaner	X				X	
Carbon removing compound		X			X	
Chlorobenzene	X			X	X	
Coal tar		X			X	X

Table 2. (Continued)

Waste Description	Candidate for Incineration[b]			Preferred Incinerator		
	Good	Potential	Poor	Liquid Injection Incinerator	Rotary Kiln	Fluidized Bed
Cleaning compound		X			X	
Corrosion/rust preventive (Tectyl)		X			X	X
Gamlen CW		X			X	X
Sandblasting grit with organotin			X	e	X	X
Walnut shell with organotin			X	e	X	X
Hydraulic fluid		X		X		
Degreaser sludge		X			X	X
Cooling oil/ cutting oil		X		X	X	X
Mixed solvent	X			X	X	X
Special hull treatment			X		X	

[a]Bench tests must be conducted on the waste streams to further define incineration characteristics and actual Btu values. Bench tests will provide vital information, such as actual incinerator operating conditions for waste destruction, and are recommended prior to constructing a facility (Ref 25).

[b]Btu ratings: In general, the following Btu ratings were assumed and used for determining candidates for incineration: Poor--5,000 Btu/lb; Potential--5,000 to 10,000 Btu/lb, Good--10,000 Btu/lb.

[c]Freon 113 should be recycled rather than incinerated and combusted.

[d]Solid paint should be disposed of in a landfill.

[e]Organotin sandblasting grit and walnut shells are problem wastes but are not considered hazardous wastes under the RCRA. However, the volume and toxicity of this waste are reduced by incineration (Ref 4). It must be emphasized that the RCRA "Mixing Rule" states that any waste mixed with hazardous waste results in the mixture being considered hazardous waste (Ref 25).

Table 3. Hazardous Waste and Incinerator Type Matrix

Characteristic	Liquid Injection	Multiple Hearth	Rotary Kiln	Fluidized Bed	Coincineration	Pyrolyzer
Waste Type:						
Low viscosity oil (<500 SSU[a]): organic toxic waste	X		X		X	X
High viscosity oil (>500 SSU): Organic liquid			X	X	X	
Solid-friable powder		X	X	X		
Solid-granular, irregular, bulky, tars, organic compounds with fusible ash			X		X	
Slurry/sludge (Solid/Liquid)		X	X	X	X	
Temperature Level:						
2,000 F	X				X	
Resultant Ash:						
Non-fusible	X	X	X	X	X	X
Fusible	X		X			
Metallic	X	X	X	X		X

[a]SSU = Seconds Saybolt Universal

Table 4. Characteristics of a Typical Rotary Kiln Incinerator
[Based on data from manufacturers and the U.S. Army]

Item	Characteristic
Feeder Mechanism	
Feed rate	4,000 to 8,000 lb/hr
Solid feed system	Screw/ram mechanisms
Liquid feed system	Liquid feed pumps
Waste types handled	Solids/liquids/semisolids
Primary Chamber (Kiln)	
Type kiln	Rotary
Inside diameter	6 ft
Length	23 ft
Refractory thickness	9 in. (firebrick)
Design temperature	1,400 to 2,600°F
Ash storage device	Ash bin
Residence time	0.5 sec to 60 min
Secondary Chamber (Afterburner)	
Inside diameter	7 ft
Refractory thickness	9 inch
Design temperature	1,600°F
Flue gas residence time	2 minutes
Induced draft fan	Corrosion resistant
Air pollution control system	Fabric filter/baghouse
Stack	Corrosion resistant with sampling ports
Heat Recovery System	
optional (highly recommended)	Waste heat boiler
Ancillary Equipment	
Emergency bypass stack	In event of malfunction
Instrument control system	Prewired with controls enclosure
Staging/receiving facility	Meets RCRA (if waste held over 90 days) and spill control counter measures (SPCC) requirements
Utility Requirements	
Estimated electrical needs	100 kW
Estimated water consumption	1,300 gal/hr
Estimated fuel requirements	No. 2 fuel oil/natural gas

Table 5. Manufacturers of Rotary Kiln Incinerators
(See Ref 25)

Company	Phone Number
Best Environmental Services and Technology South Hampton, PA	(215) 322-5016
CE Industries Corp. Bellville, IL	(618) 233-0129
CE-Raymond, Combustion Engineering Chicago, IL	(312) 369-3700
College Research Corp. Germantown, WI	(414) 255-4700
Edward Renneburg & Sons Inc. Baltimore, MD	(301) 732-1666
Environmental Elements Corp. Baltimore, MD	(301) 368-6737
Ford, Bacon and Davis Salt Lake City, UT	(801) 583-3773
Fuller (GATX) Bethlehem, PA	(215) 264-6011
HED Ringoes, NJ	(609) 466-1900
Incinerator International, Inc. Houston, TX	(713) 227-1466
Industronics, Inc. South Windsor, CT	(203) 289-1551
International Waste Energy Systems Inc. St. Louis, MO	(314) 389-7275
Kennoy-Van Sann Corp. Danville, PA	(717) 275-3050
MS Manufacturing Co. Broad Brook, CT	(203) 627-9396

Table 5. (Continued)

Company	Phone Number
Met-Pro Harleysville, PA	(215) 723-6751
Midland-Ross Corp.[a] Toledo, OH	(419) 537-6444
Phillips Kiln Services Sioux City, IO	(800) 831-0876
Pyro-Tech Systems Inc. Tullahoma, TN	(615) 797-9122
Resource Recovery International Bossier, LA	(318) 747-0752
TR Systems of New Jersey Livingston, NJ	(201) 994-9567
Therm-Tec Tualatin, OR	(503) 692-1490
Thermacon Dunedin, FL	(813) 733-2171
Therm-ALL Peapack, NJ	(201) 234-1776
Vulcan Iron Works Wilkes-Barre, PA	(717) 822-2161
Warwick Furnace Co. Wheeling, IL	(312) 459-2700

[a]Indicates companies that provided information for this study. Others were based on U.S. Army data.

Table 6. Summary of Estimated Capital Costs ($)

Item	FY85	FY88	FY90
Direct Capital Costs (DCC)			
Incinerator feed system	175,000	200,000	220,000
Primary chamber (kiln)	350,000	400,000	440,000
Afterburner	175,000	200,000	220,000
Heat recovery boiler	190,000	220,000	240,000
Air pollution control (APC)	180,000	208,000	228,000
Flue gas handling equipment (fan/ductwork/dampers/stack)	90,000	104,000	114,000
Ash handling system	25,000	29,000	32,000
Controls and instrumentation	120,000	138,000	152,000
Drum loading system	75,000	86,000	95,000
Subtotal	1,380,000	1,585,000	1,741,000
Indirect Capital Costs (ICC)			
Construction/erection and utilities installation	575,000	661,000	727,000
Bench tests	50,000	58,000	64,000
Trial burns	150,000	173,000	190,000
Engineering (at 7% of DCC)	90,000	104,000	114,000
Permits, plans and Environmental Impact Report (EIR)	225,000	259,000	285,000
Startup/training	50,000	58,000	64,000
Spare parts	60,000	69,000	76,000
Staging/receiving area	100,000	115,000	125,000
Freight (f.o.b. Honolulu) (Ref 15)	40,000	46,000	51,000
Subtotal	1,340,000	1,543,000	1,696,000
Contingency (10% DCC + ICC)	272,000	312,000	344,000
Total Capital Costs	2,992,000	3,440,000	3,781,000

NOTES: (assumptions)

1. Based on 5% per year inflation.
2. Based on permits, plans, and EIR costs for similar projects.
3. Staging area for short-term storage, loading, and unloading.
4. Direct and indirect capital costs are based on Ref 12 through 22.
5. Revised as per Ref 25.

Table 7. Summary of Estimated Operation and Maintenance (O&M) Costs ($)
[Numbers are rounded to nearest thousand dollars.]

Category	Scenario A[a]	Scenario B[a]
Auxiliary Fuel	929,000	929,000
Electricity	63,000	63,000
Water	9,000	9,000
Wastewater/Chemicals	11,000	11,000
Ash Disposal	263,000	263,000
Maintenance/Repair/ Inspection	133,000	133,000
Labor	120,000	120,000
Subtotal O&M Costs	1,528,000	1,528,000
Burden (at 5% O&M)	76,000	76,000
Total O&M Costs	1,604,000	1,604,000
Savings/Benefit for Steam Produced	-461,000[b]	-1,507,000[b]
Adjusted New O&M Costs	1,143,000	97,000

[a]Both scenarios are based on firing a 50/50 ratio of auxiliary fuel and hazardous waste at a rate of 6,000 lb/hr, 24/hr day, 329 days/yr assuming 10% downtime. Scenarios A and B consider the waste to have a heat value of 0 Btu/lb and 5,000 Btu/lb, respectively.

[b]Net savings from waste recovery boiler calculated using values from Tables 9 and 10.

Table 8. Steam Generation From Waste Heat Recovery Boiler

Feed Rate of Waste (lb/hr)	Amount of Steam Generated (lb/hr) at Heat Value of--				
	0 Btu/lb	5,000 Btu/lb	7,500 Btu/lb	10,000 Btu/lb	15,000 Btu/lb
2,000	7,274	12,788	15,533	18,288	23,798
4,000	7,274	18,288	23,798	29,308	40,328
6,000	7,274	23,800	32,063	40,328	56,858
8,000	7,274	29,308	40,328	51,348	73,388
10,000	7,274	34,818	48,593	62,368	94,540

Note: All steam generation includes continuous auxiliary firing.

Table 9. Annual Saving From Waste Heat Recovery Boiler (329 Days Operation, About 10% Downtime)

[Value of steam: $10/1,000 lb steam]

Feed Rate of Waste (lb/hr)	Annual Saving ($) at Heat Value of--				
	0 Btu/lb	5,000 Btu/lb	7,500 Btu/lb	10,000 Btu/lb	15,000 Btu/lb
2,000	574,355	1,009,740	1,223,880	1,444,178	1,879,248
4,000	574,355	1,444,020	1,879,248	2,313,528	3,182,088
6,000	574,355	1,878,248	2,531,458	3,182,088	4,489,666
8,000	574,355	2,313,528	3,182,088	4,054,586	5,784,874
10,000	574,355	2,747,808	3,836,666	4,824,735	7,461,720

Note: All steam generation includes continuous auxiliary firing.

Table 10. Annual O&M Costs for Waste Heat Recovery Boiler

Feed Rate of Waste (lb/hr)	Annual O&M Cost ($) at Heat Value of--				
	0 Btu/lb	5,000 Btu/lb	7,500 Btu/lb	10,000 Btu/lb	15,000 Btu/lb
2,000	113,474	199,493	242,268	285,324	371,280
4,000	113,474	285,293	371,280	457,080	628,680
6,000	113,474	371,280	500,136	629,148	886,860
8,000	113,474	457,080	628,680	801,060	1,144,884
10,000	113,474	542,880	758,160	972,972	1,474,200

Note: All steam generation includes continuous auxiliary firing. All O&M costs are based on a constant increase in cost of $1.78/1,000 lb/ton of steam generated. This reflects increases in operational time and maintenance for heat exchangers (tubes) and water treatment systems and chemicals.

Table 11. Companies Capable of Providing Testing, Permit Application Preparation and Environmental Impact Report Services

Company	Phone Number
Energy and Environmental Research Corp. 18 Mason Irvine, CA 92718	(714) 859-8851
Environmental Research and Technology 2625 Townsgate Rd. Westlake Village, CA 91361	(805) 497-0821
Systech Corp. 245 North Valley Road Xenia, OH 45385	(513) 372-8077

Note: List is not all inclusive

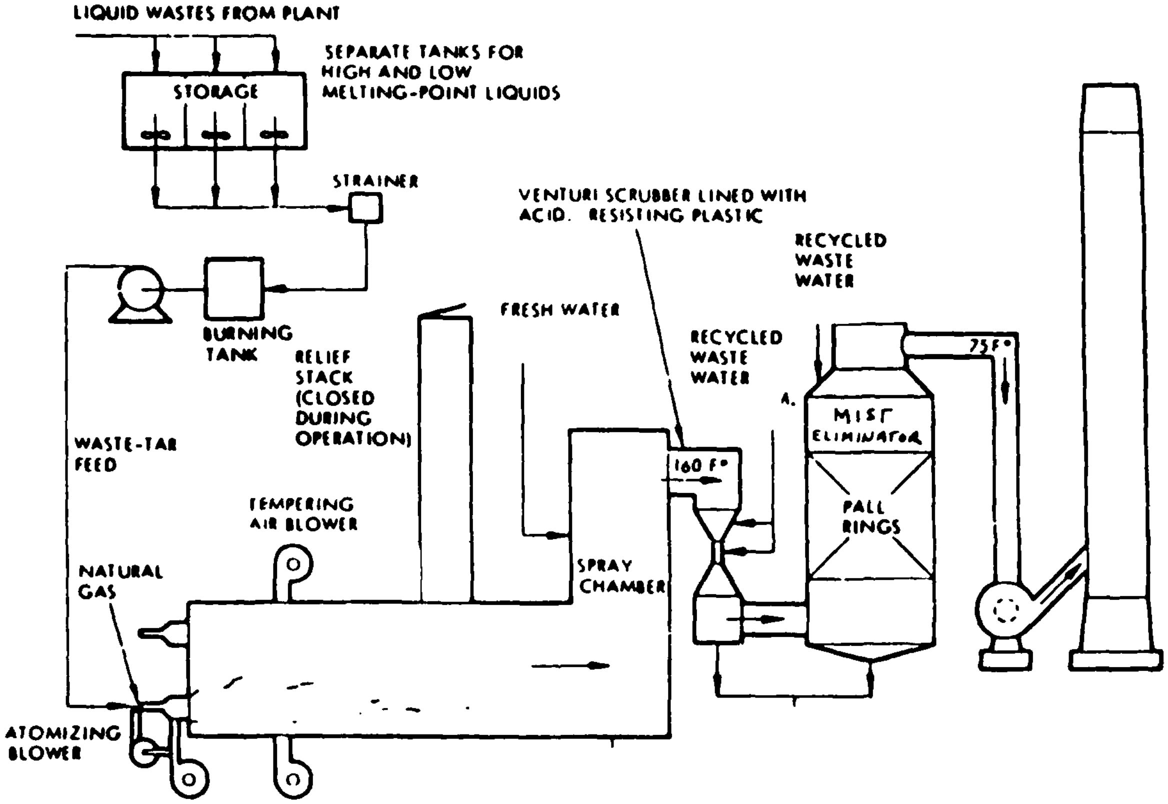


Figure 1. Horizontally fired liquid injection hazardous waste incineration system.

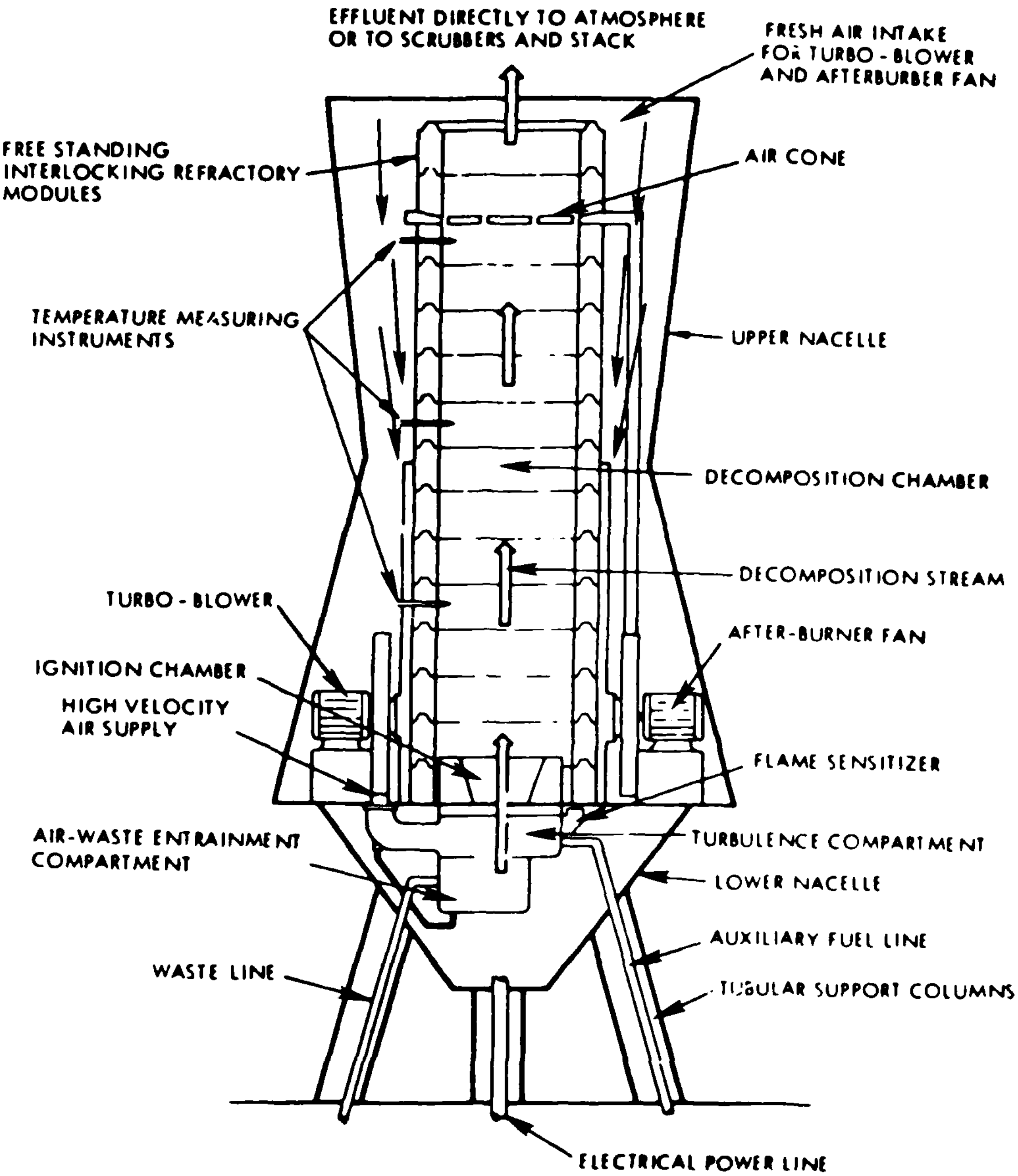


Figure 2. Typical vertically fired liquid waste incinerator.

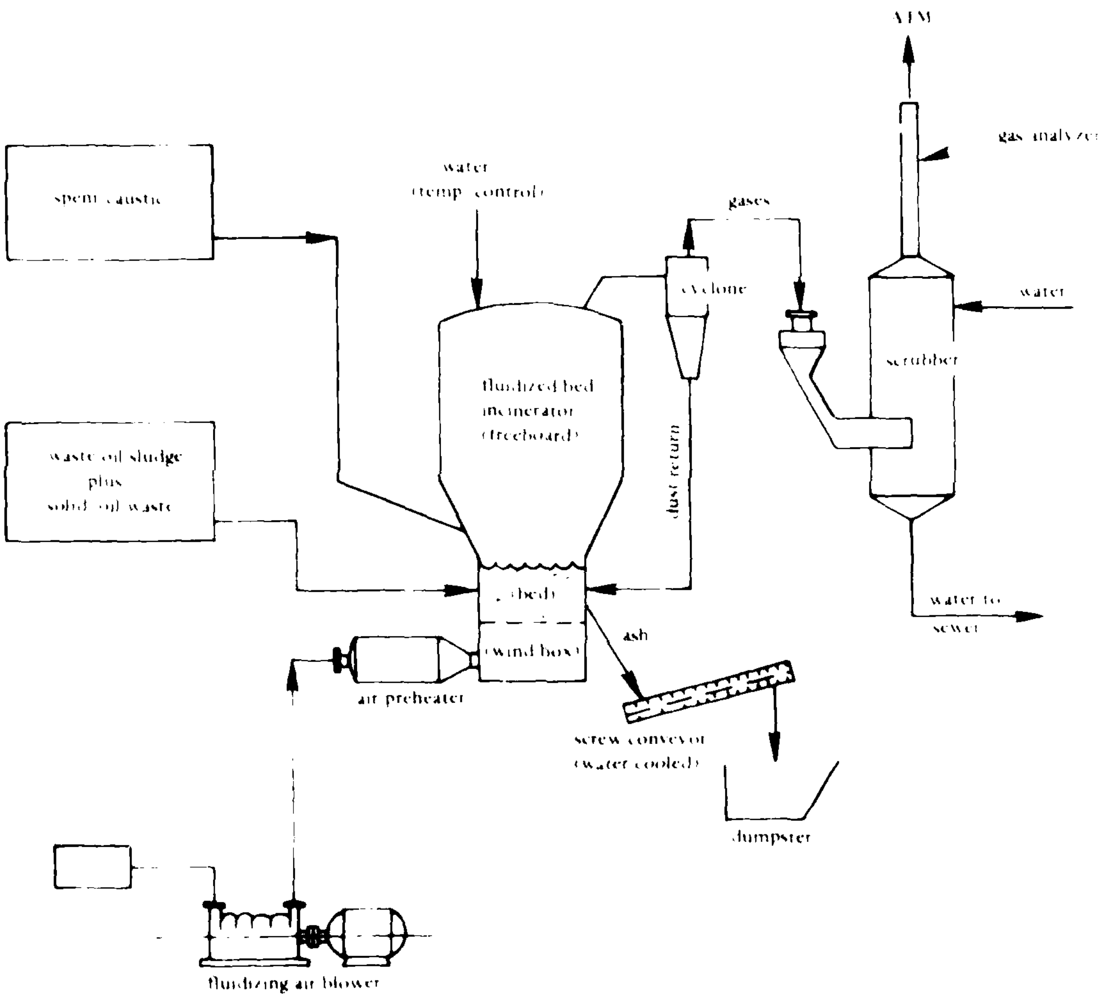


Figure 3. Fluidized bed incinerator.

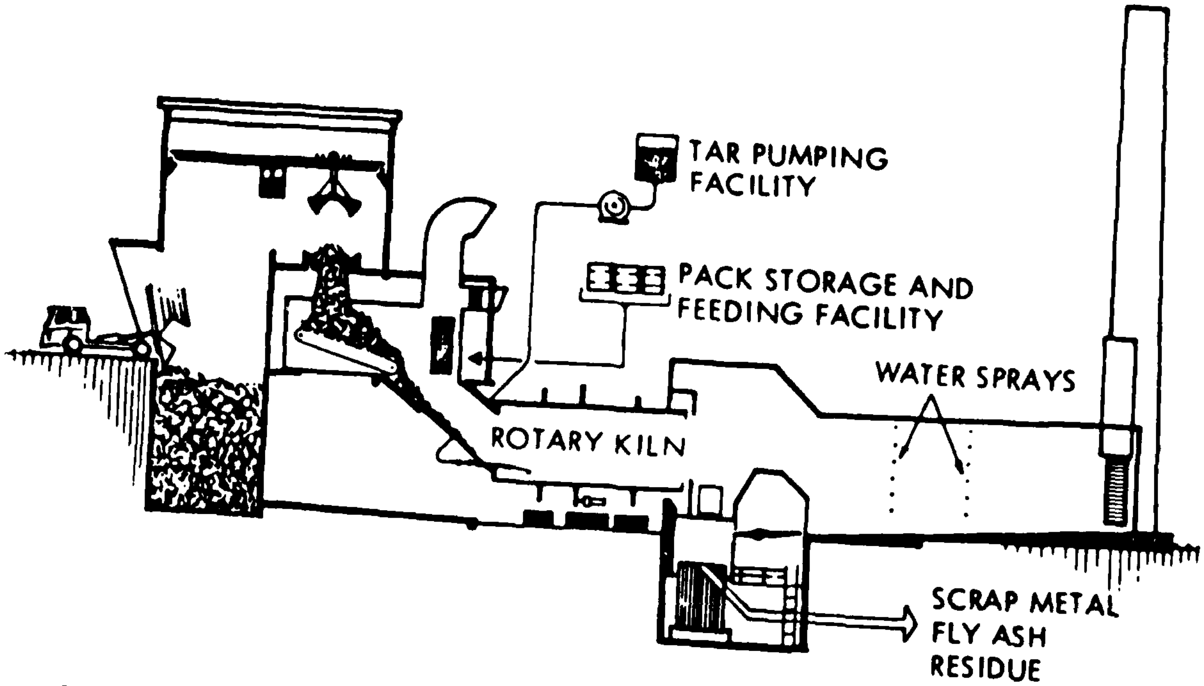
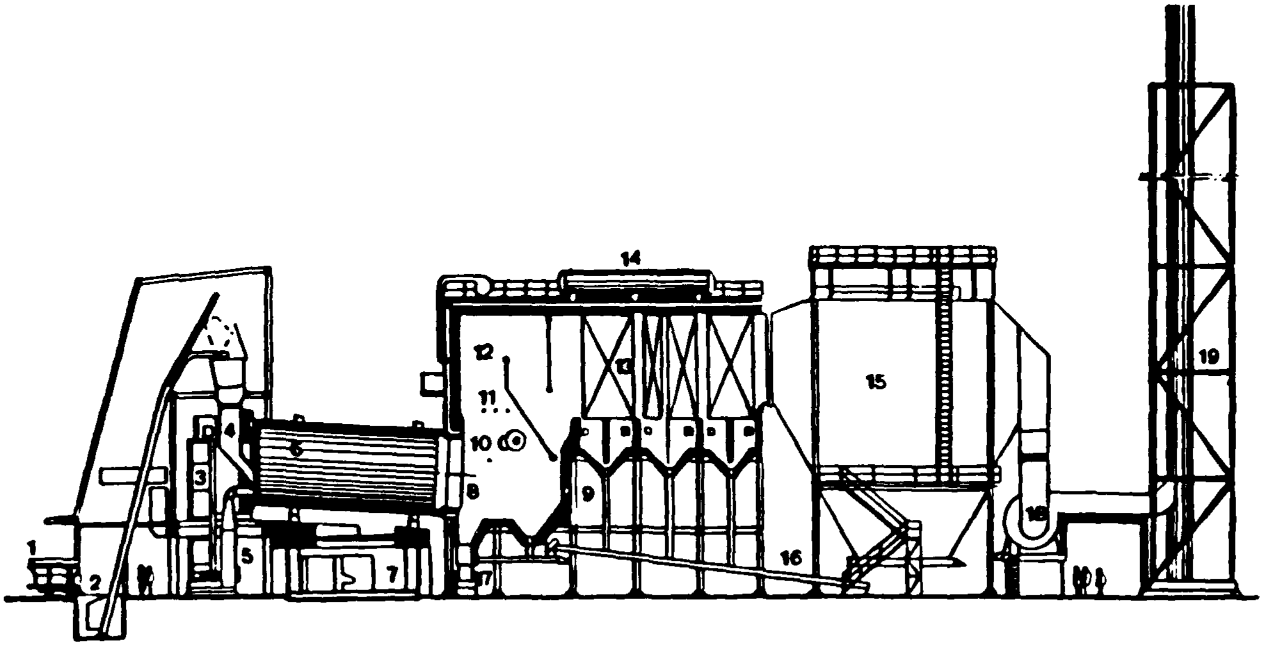


Figure 4. Typical major industrial rotary kiln incineration facility.



1. Waste Reception Area
2. Buckel Elevator
3. Barrel Elevator
4. Feed Chute
5. Primary Air
6. Rotary Kiln
7. Control Room
8. Secondary Combustion Chamber
9. Lances For Wastewater
10. Burner For Waste Oil
11. Secondary Air
12. Tertiary Air
13. Waste Heat Boiler
14. Boiler Drum
15. Electrostatic Precipitator
16. Fly Ash Handling
17. Residue Handling
18. Induced Draught Fan
19. Stack

Figure 5. Typical longitudinal section of a rotary kiln system.

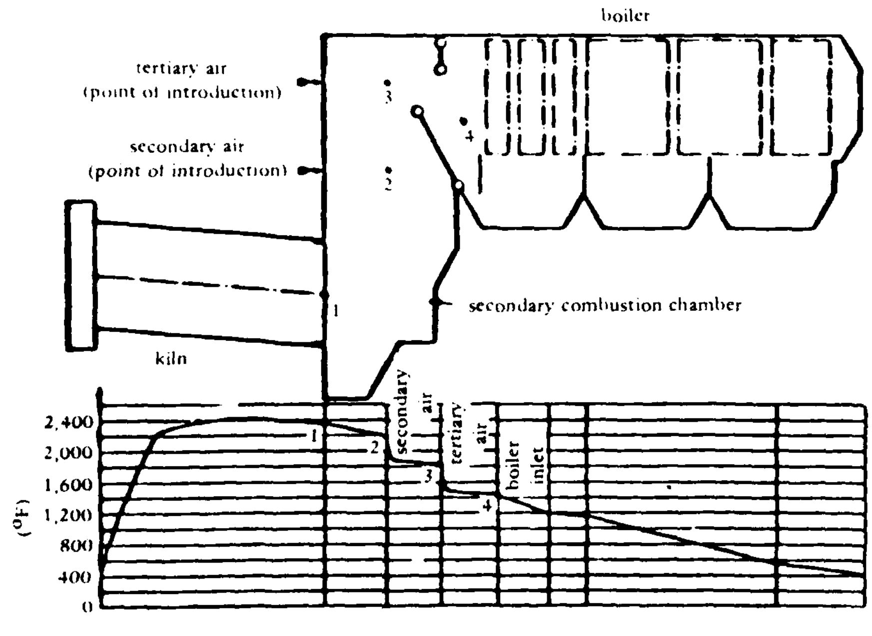


Figure 6. Typical gas temperature profile of incineration train.

Source: Manufacturer's data

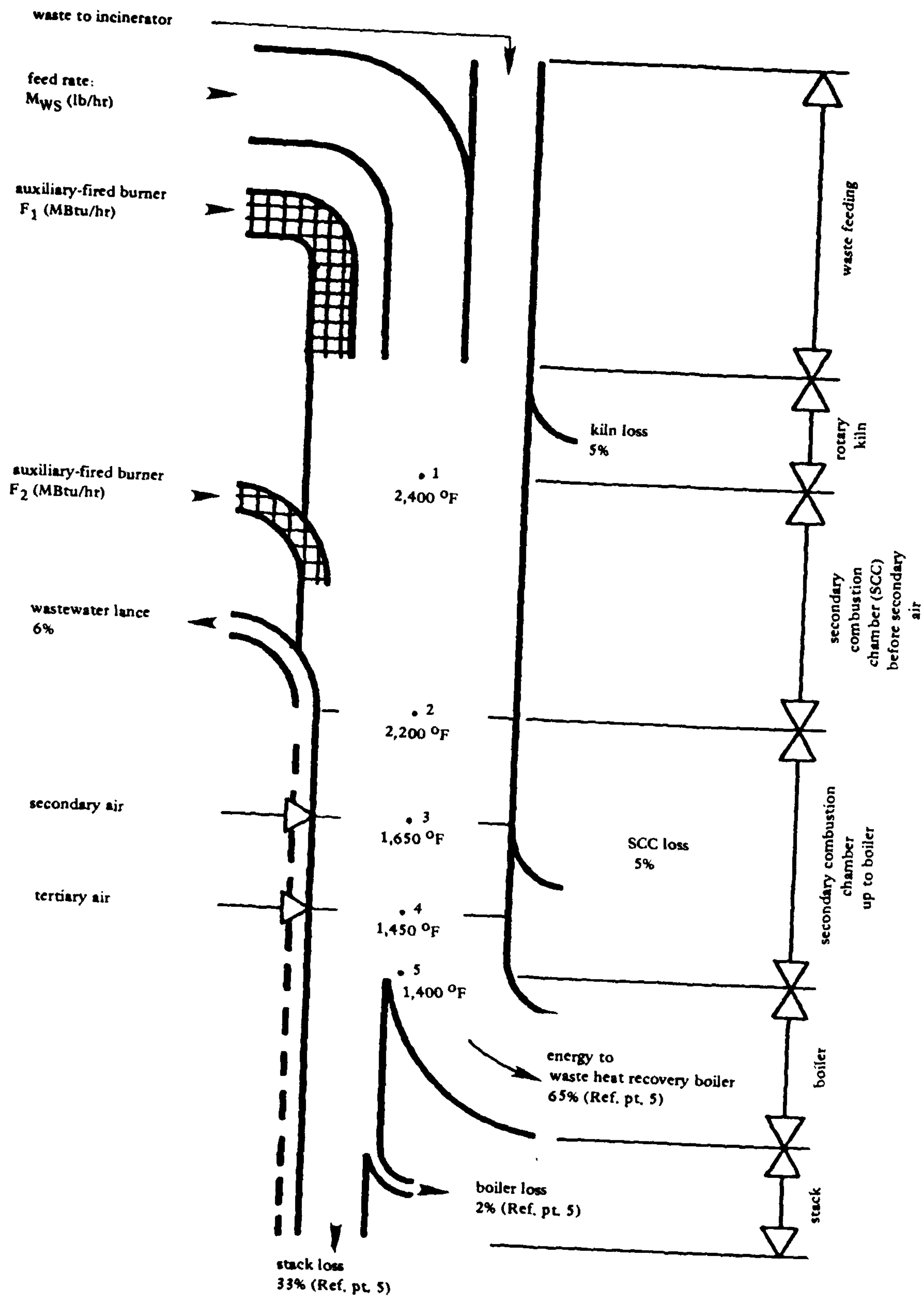


Figure 7. Steam generation versus waste input.

Source: NCEL 1985

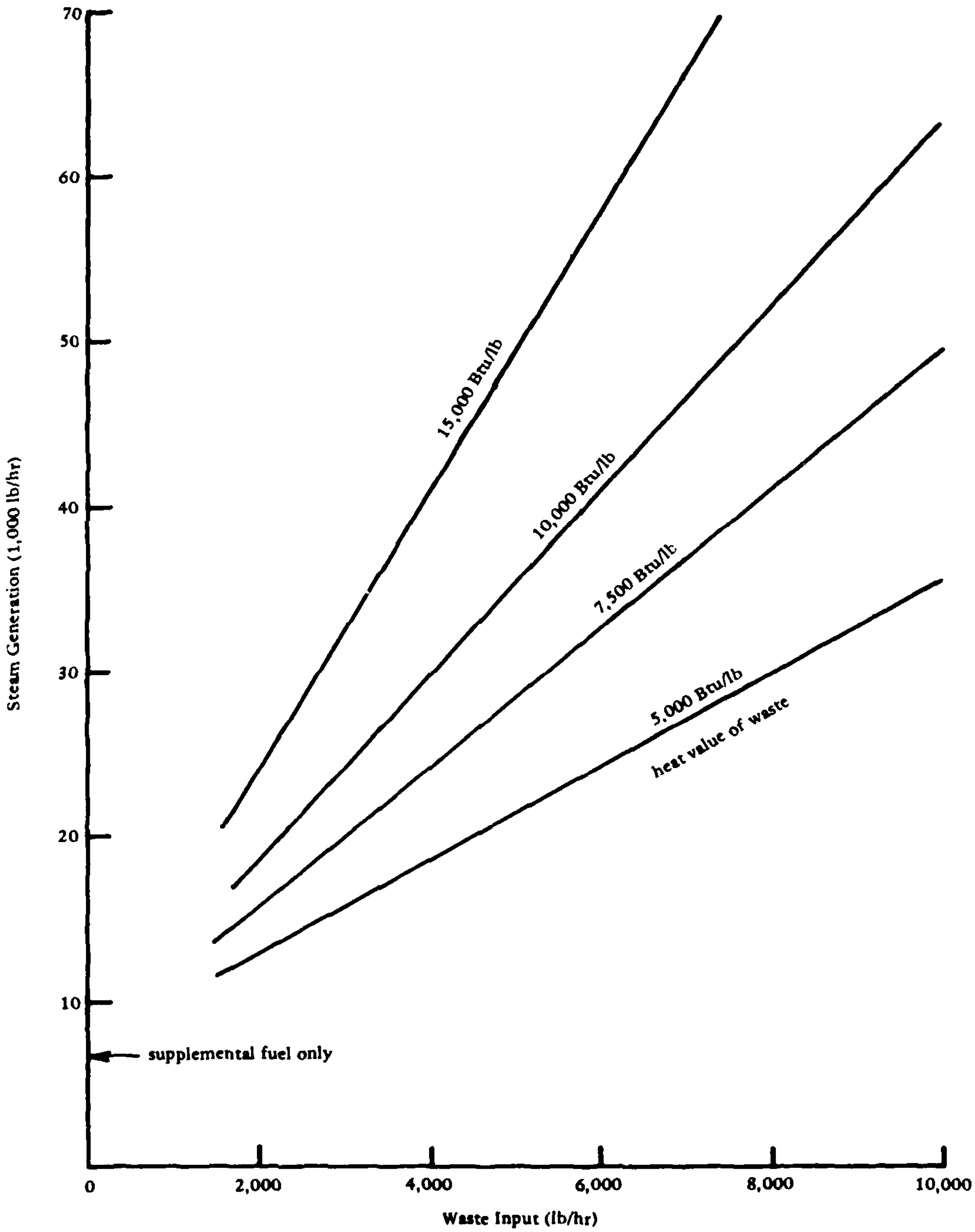


Figure 8. Schematic of rotary kiln system energy balance.

Source: NCEL 1985

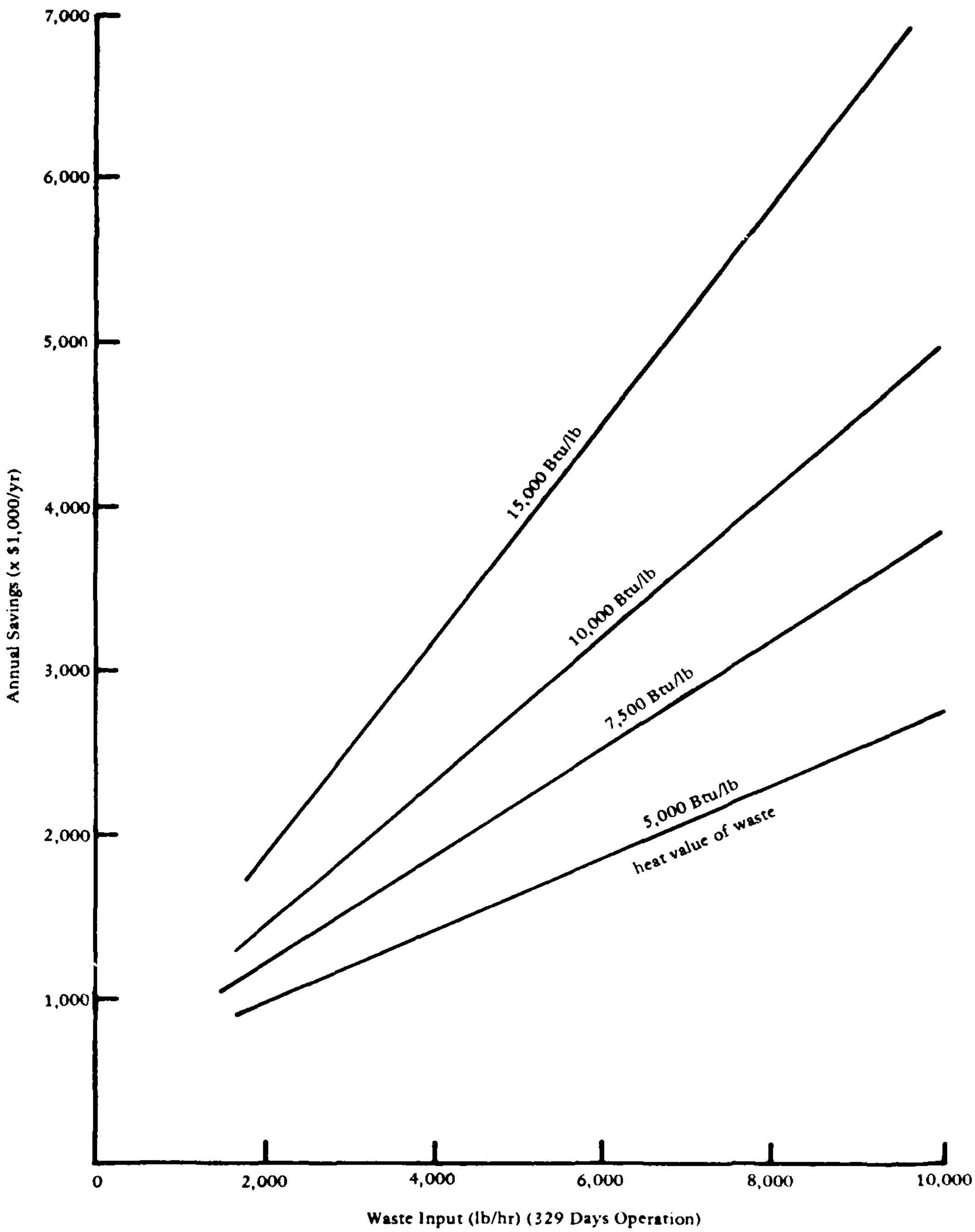
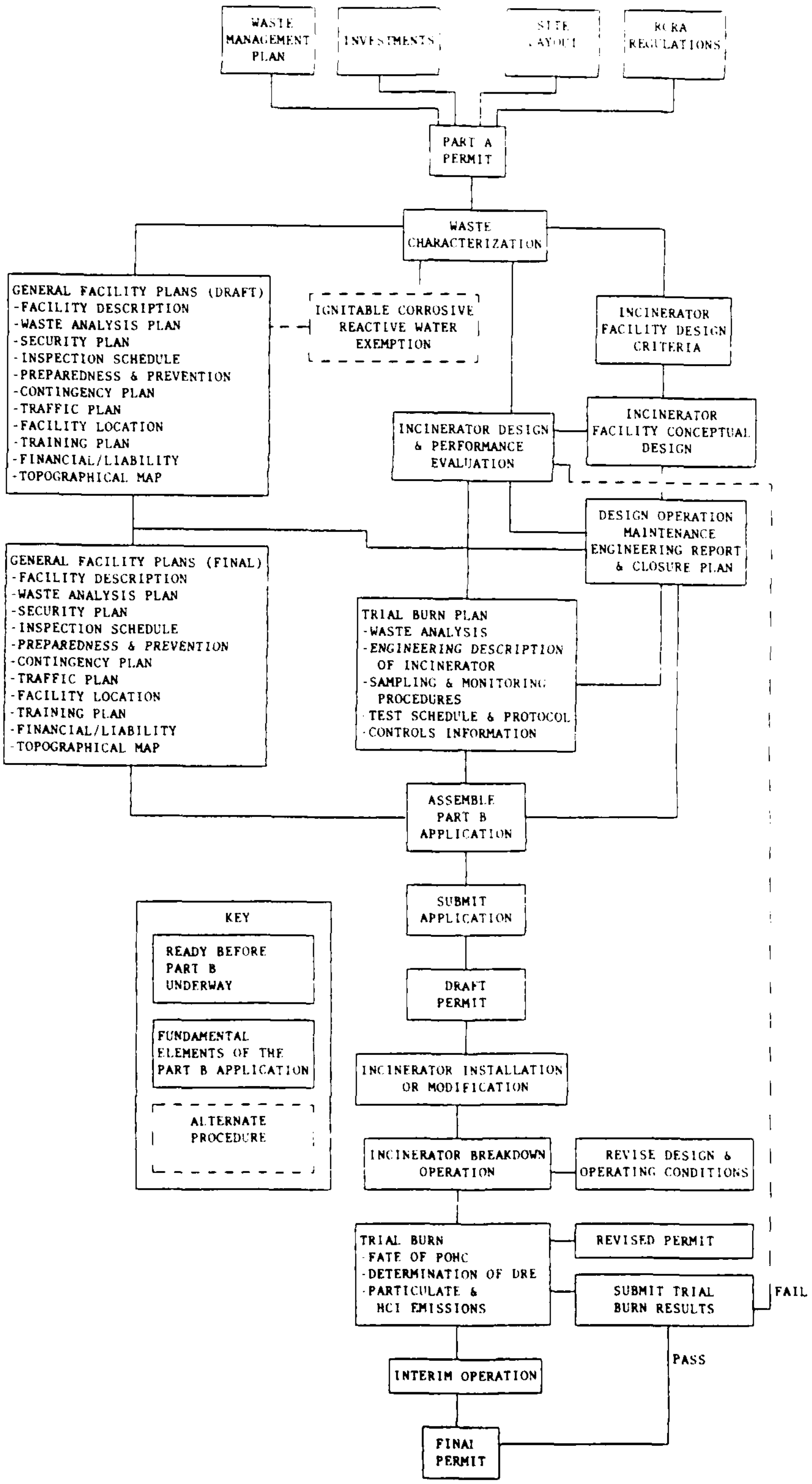


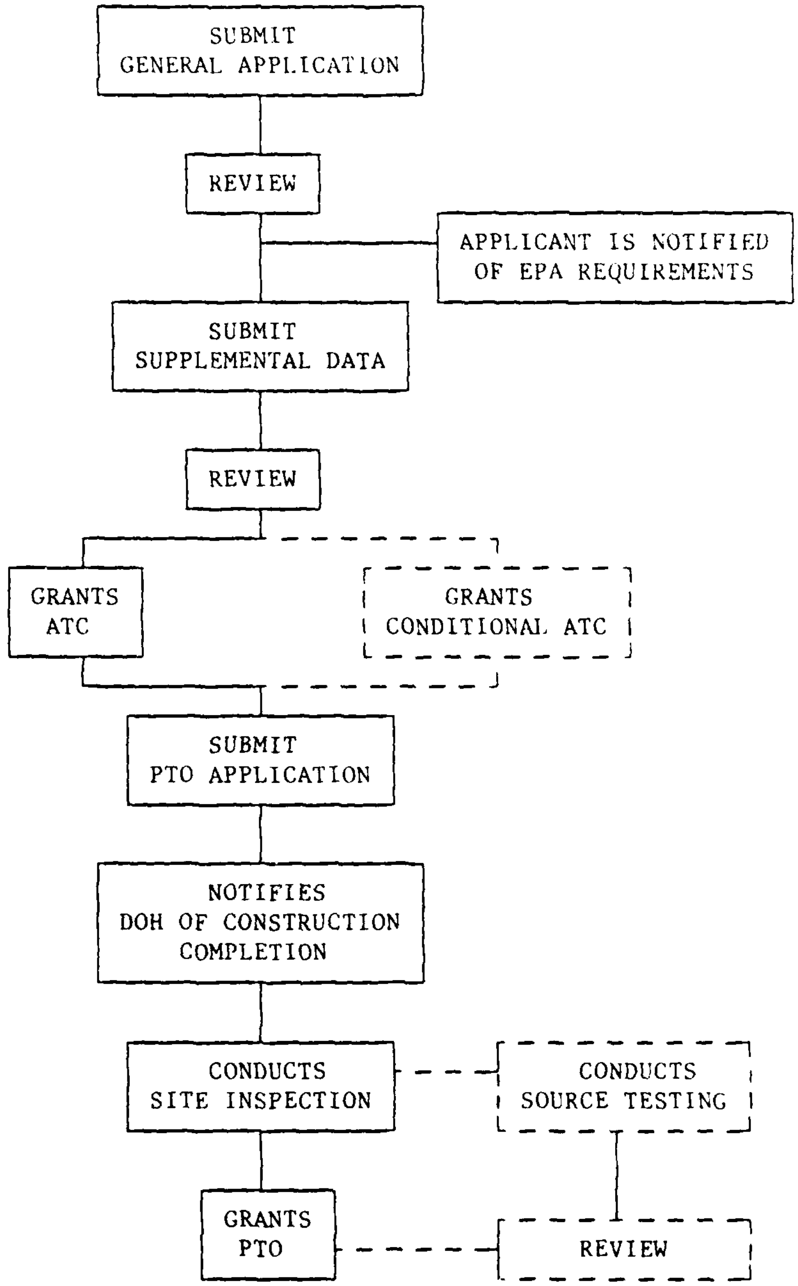
Figure 9. Annual savings from waste heat recovery boiler (Value of steam: $10/MBtu).

Source: NCEL 1985



SOURCE: ENVIRONMENTAL RESEARCH AND TECHNOLOGY (ER&T) 1984

Figure 10. Steps in preparing a RCRA incinerator permit application (from Ref 29).



SOURCE: NCEL

Figure 11. Steps in preparing State of Hawaii permit application for an incinerator.

DISTRIBUTION LIST

AFB 3480 CES/DEEV, Goodfellow AFB, TX; SAMSO/MNND, Norton AFB CA

AFESC DEB, Tyndall AFB, FL; HQ AFESC/TST, Tyndall AFB FL; HQ RDC [illegible] AFB [illegible]; HQ TST, Tyndall AFB, FL

ARMY Ch of Engrs, DAEN-CWE-M, Washington, DC; ERADCOM Tech Supp Dir. (DELSD-L) Ft. Monmouth, NJ; POJED-O, Okinawa, Japan

ARMY CERL Library, Champaign IL

ARMY CORPS OF ENGINEERS HNDED-CS, Huntsville, AL; HNDED-SY, Huntsville, AL

ARMY DEPOT Letterkenny, Fac Engr (SDSLE-SE), Chambersburg, PA

ARMY ENVIRON. HYGIENE AGCY Dir, Env Qual, Aberdeen Proving Grnd, MD

ARMY EWES Library, Vicksburg MS

ARMY MAT & MECH RSCH CEN DRXMR-SM (Lenoe), Watertown, MA

ARMY-ARADCOM STINFO Div, Dover, NJ

ARMY-BELVOIR R&D CTR STRBE-WC, Ft Belvoir, VA

CBC Code 10, Davisville, RI; Dir, CESO, Port Hueneme, CA; Library, Davisville, RI; PWO (Code [illegible]), Port Hueneme, CA; PWO, Gulfport, MS; Tech Library, Gulfport, MS

CINCUSNAVEUR London, England

CNO Code NOP-964, Washington, DC; Code OP 44H, Washington, DC; Code OP 45, Washington, DC; Code OP 98, Washington, DC

COGARD R AND DC Library, Groton, CT

COMDT COGARD Library, Washington, DC

COMFAIRMED SCE, Naples, Italy

COMFLEACT PWO, Okinawa, Japan; SCE, Yokosuka Japan

COMFLEACT, OKINAWA PWO, Kadena, Japan

COMNAVMARIANAS CO, Guam

COMSC Washington DC

DLSIE Army Logistics Mgt Center, Fort Lee, VA

DOD DDR&E, Washington, DC; DFR NE, O'Donovan, PE, McGuire AFB, NJ

DTIC Alexandria, VA

DTNSRDC Code 4111, Bethesda, MD; Code 42, Bethesda MD; DET Code 2834, Annapolis, MD; DET Code 522 (Library), Annapolis, MD

FAA CAMI Lib, Oklahoma City, OK

FMFPAC G5 (SCIAD), Camp HM Smith, HI

GSA Code FAIA, Washington, DC; *Code PCDP, Washington, DC*

MARINE CORPS BASE ACOS Fac Engr, Okinawa; Dir, Maint Control, PWD, Okinawa, Japan; PWO, Camp Lejeune, NC; PWO, Camp Pendleton, CA

MARINE CORPS HQTRS Code LFF-2, Washington DC

MCAF Code C144, Quantico, VA

MCAS Dir, Ops Div, Fac Maint Dept, Cherry Point, NC; PWO, Kaneohe Bay, HI; PWO, Yuma, AZ

MCLB PWO (Code B520), Barstow, CA

NALF OIC, San Diego, CA

NAS Code 0L, Alameda, CA; Code 182, Bermuda; Code 187, Jacksonville, FL; Code 72E, Willow Grove, PA; Code 8E, Patuxent River, MD; Director, Engrg. Div, PW (Code 182HI), Miramar, San Diego, CA; PWO Beeville, TX; PWO, Cecil Field, FL; PWO, Dallas TX; PWO, Glenview IL; PWO, Keflavik, Iceland; PWO Key West, FL; PWO, Kingsville TX; PWO, Millington, TN; PWO, Miramar, San Diego CA; PWO, Moffett Field, CA; PWO, New Orleans, LA; PWO, Sigonella, Sicily; PWO, South Weymouth, MA; PWO, Willow Grove, PA; SCE, Cubi Point, RP; Whiting Fld, PWO, Milton, FL; Wpns Offr, NI, San Diego, CA

NATL BUREAU OF STANDARDS Bldg Mat Div (Rossiter), Gaithersburg, MD

NAVAIRDEVCEN Code 832, Warminster, PA

NAVAIRENGCEN Code 182, Lakehurst, NJ

NAVAIREWORKFAC Code 640, Pensacola FL; Code 64116, San Diego, CA; SCE, Norfolk, VA

NAVAIRPROPTESTCEN CO, Trenton, NJ

NAVAVIONICCEN Deputy Dir, PWD (Code D/701), Indianapolis, IN; PW Div, Indianapolis, IN

NAVCAMS SCE (Code N-7), Naples, Italy; SCE (Code W-60), Wahiawa, HI

NAVCOASTSYSCEN Code 630, Panama City, FL; Tech Library, Panama City, FL

NAVCOMMSTA Code 401, Nea Makri, Greece; PWO, Exmouth, Australia

NAVCONSTRACEN Code D2A, Port Hueneme, CA

NAVEDTRAPRODEVCEN Tech Lib, Pensacola, FL

NAVENVIRHLTHCEN Code 642, Norfolk, VA

NAVEODTECHCEN Tech Library, Indian Head, MD

NAVFACENGCOM Code 03, Alexandria, VA; Code 03T (Essoglou), Alexandria, VA; Code 09M124 (Tech Lib), Alexandria, VA

NAVFACENGCOM - CHES DIV. Code 101, Washington, DC; Code 405, Washington, DC; Code FPO-1PL Washington, DC

NAVFACENGCOM - LANT DIV. Code 405, Norfolk, VA; Library, Norfolk, VA

NAVFACENGCOM - NORTH DIV. CO, Philadelphia, PA; Code 04AL, Philadelphia, PA; [illegible] Philadelphia, PA
NAVFACENGCOM - PAC DIV. Code 09P, Pearl Harbor, HI; Code [illegible] Pearl Harbor, HI; Code 402, RDT&E LnO, Pearl Harbor, HI; Library, Pearl Harbor, HI
NAVFACENGCOM - SOUTH DIV. Code 1112, Charleston, SC; Library, Charleston, SC
NAVFACENGCOM - WEST DIV. 09P/20, San Bruno, CA; Br Offc, Code [illegible], San Diego, CA; [illegible] San Bruno, CA; Library (Code 04A2.2), San Bruno, CA; RDT&E LnO, San Bruno, CA
NAVFACENGCOM CONTRACTS OICC, Guam
NAVHOSP SCE, Pensacola FL
NAVMARCORESCEN LTJG Davis, Raleigh, NC
NAVOCEANSYSCEN Code 964 (Tech Library), San Diego, CA
NAVORDSTA PWO, Louisville, KY
NAVPGSCOL E. Thornton, Monterey, CA
NAVPHIBASE PWO, Norfolk, VA; SCE, San Diego, CA
NAVSCOLCECOFF Code C35, Port Hueneme, CA
NAVSEASYSCOM Code 05M, Washington, DC; Code 06H4, Washington, DC; Code CEL [illegible], Washington, DC
NAVSECGRUACT PWO, Sabana Seca, PR
NAVSHIPYD Code 202.5 (Library), Bremerton, WA; Code 30P (G. Miyasaki), Pearl Harbor, HI; Code 440, Bremerton, WA; Code 440, Portsmouth, NH; Dir, PWD (Code 420), Portsmouth, VA; Library, Portsmouth, NH; PWD, Long Beach, CA; PWO, Bremerton, WA; PWO, Charleston, SC; PWO, Mare Island, Vallejo, CA; SCE, Pearl Harbor, HI
NAVSTA CO, Brooklyn, NY; Code 18, Midway Island; Dir, Engr Div, PWD, [illegible]; Engr Dir, Rota Spain; PWO, Mayport, FL; SCE, Guam, Marianas Islands; Util Engrg Offr, Rota, Spain
NAVSUPPACT PWO, Holy Loch, UK; PWO, Naples, Italy
NAVSUREWPNCEN DET, PWO, White Oak, Silver Spring, MD; PWO, Dahlgren, VA
NAVTECHTRACEN SCE, Pensacola FL
NAVTRASTA SCE, San Diego, CA
NAVWPNCEN PWO (Code 266), China Lake, CA
NAVWPNSFAC Wpns Offr, St. Mawgan, England
NAVWPNSTA Code 092, Colts Neck, NJ; Code 092, Concord CA; PWO, Charleston, SC; PWO, Code [illegible], Colts Neck, NJ; PWO, Seal Beach, CA
NAVWPNSTA PWO, Yorktown, VA
NAVWPNSUPPCEN Code 09, Crane, IN
NETC Code 42, Newport, RI; PWO, Newport, RI; Utilities Dir, Code [illegible], Newport, RI
NMCB 5, Operations Dept
NOAA Library, Rockville, MD
NSC Cheatham Annex, PWO, Williamsburg, VA; Fac & Equip Div, Code [illegible], Oakland, CA; SCE, Norfolk, VA
NUSC DET Code 401 (RS Munn), New London, CT; Code 5202 (S. Schady), New London, CT; Code SB [illegible] (Brown), Newport, RI
OCNR Code 1234, Arlington, VA; Code 33, Arlington, VA; DET, Code 48, Bay St. Louis, MS
PWC Code 10, Oakland, CA; Code 101 (Library), Oakland, CA; Code [illegible], Oakland, CA; Code [illegible], San Diego, CA; Code 30V, Norfolk, VA; Code 400, San Diego, CA; Code 420, Great Lakes, IL; Code 420, Oakland, CA; Code 438 (Aresto), San Diego, CA; Code 500, Oakland, CA; Code 590, San Diego, CA; Code 610, San Diego Ca; Library (Code 134), Pearl Harbor, HI; Library, Guam, Mariana Islands; Library, Norfolk, VA; Library, Pensacola, FL; Library, Yokosuka, JA; Tech Library, Subic Bay, RP
SPCC PWO (Code 08X), Mechanicsburg, PA
SUPSHIP Tech Library, Newport News, VA
USDA Forest Prod Lab, Libr, Madison, WI
USNA PWO, Annapolis, MD

INSTRUCTIONS

The Naval Civil Engineering Laboratory has revised its primary distribution lists. The bottom of the mailing label has several numbers listed. These numbers correspond to numbers assigned to the list of Subject Categories. Numbers on the label corresponding to those on the list indicate the subject category and type of documents you are presently receiving. If you are satisfied, throw this card away (or file it for later reference).

If you want to change what you are presently receiving:

- Delete – mark off number on bottom of label.
- Add – circle number on list.
- Remove my name from all your lists – check box on list.
- Change my address – line out incorrect line and write in correction (ATTACH MAILING LABEL).
- Number of copies should be entered after the title of the subject categories you select.

Fold on line below and drop in the mail.

Note: Numbers on label but not listed on questionnaire are for NCEL use only, please ignore them.

Fold on line and staple.

DEPARTMENT OF THE NAVY

NAVAL CIVIL ENGINEERING LABORATORY
PORT HUENEME, CALIFORNIA 93043

OFFICIAL BUSINESS
PENALTY FOR PRIVATE USE, $300
1 IND-NCEL-2700/4 (REV. 12-73)
0930-LL-L70-0044

POSTAGE AND FEES PAID
DEPARTMENT OF THE NAVY
DOD-316

Commanding Officer
Code L14
Naval Civil Engineering Laboratory
Port Hueneme, California 93043

DISTRIBUTION QUESTIONNAIRE

The Naval Civil Engineering Laboratory is revising its primary distribution lists.

SUBJECT CATEGORIES

1 SHORE FACILITIES
2 Construction methods and materials (including corrosion control, coatings)
3 Waterfront structures (maintenance/deterioration control)
4 Utilities (including power conditioning)
5 Explosives safety
6 Construction equipment and machinery
7 Fire prevention and control
8 Antenna technology
9 Structural analysis and design (including numerical and computer techniques)
10 Protective construction (including hardened shelters, shock and vibration studies)
11 Soil/rock mechanics
13 BEQ
14 Airfields and pavements
15 ADVANCED BASE AND AMPHIBIOUS FACILITIES
16 Base facilities (including shelters, power generation, water supplies)
17 Expedient roads/airfields/bridges
18 Amphibious operations (including breakwaters, wave forces)
19 Over-the-Beach operations (including containerization, material transfer, lighterage and cranes)
20 POL storage, transfer and distribution
24 POLAR ENGINEERING
24 Same as Advanced Base and Amphibious Facilities, except limited to cold-region environments
28 ENERGY/POWER GENERATION
29 Thermal conservation (thermal engineering of buildings, HVAC systems, energy loss measurement, power generation)
30 Controls and electrical conservation (electrical systems, energy monitoring and control systems)
31 Fuel flexibility (liquid fuels, coal utilization, energy from solid waste)
32 Alternate energy source (geothermal power, photovoltaic power systems, solar systems, wind systems, energy storage systems)
33 Site data and systems integration (energy resource data, energy consumption data, integrating energy systems)
34 ENVIRONMENTAL PROTECTION
35 Solid waste management
36 Hazardous/toxic materials management
37 Wastewater management and sanitary engineering
38 Oil pollution removal and recovery
39 Air pollution
40 Noise abatement
44 OCEAN ENGINEERING
45 Seafloor soils and foundations
46 Seafloor construction systems and operations (including diver and manipulator tools)
47 Undersea structures and materials
48 Anchors and moorings
49 Undersea power systems, electromechanical cables, and connectors
50 Pressure vessel facilities
51 Physical environment (including site surveying)
52 Ocean-based concrete structures
53 Hyperbaric chambers
54 Undersea cable dynamics

TYPES OF DOCUMENTS

85 Techdata Sheets
86 Technical Reports and Technical Notes
82 NCEL Guide & Updates
☐ None— remove my name
83 Table of Contents & Index to TDS
91 Physical Security

PLEASE HELP US PUT THE ZIP IN YOUR MAIL! ADD YOUR FOUR NEW ZIP DIGITS TO YOUR LABEL (OR FACSIMILE), STAPLE INSIDE THIS SELF-MAILER, AND RETURN TO US.

(fold here)

DEPARTMENT OF THE NAVY

NAVAL CIVIL ENGINEERING LABORATORY
PORT HUENEME, CALIFORNIA 93043-5003

Commanding Officer
Code L14
Naval Civil Engineering Laboratory
Port Hueneme, California 93043-5003

FILM

5–